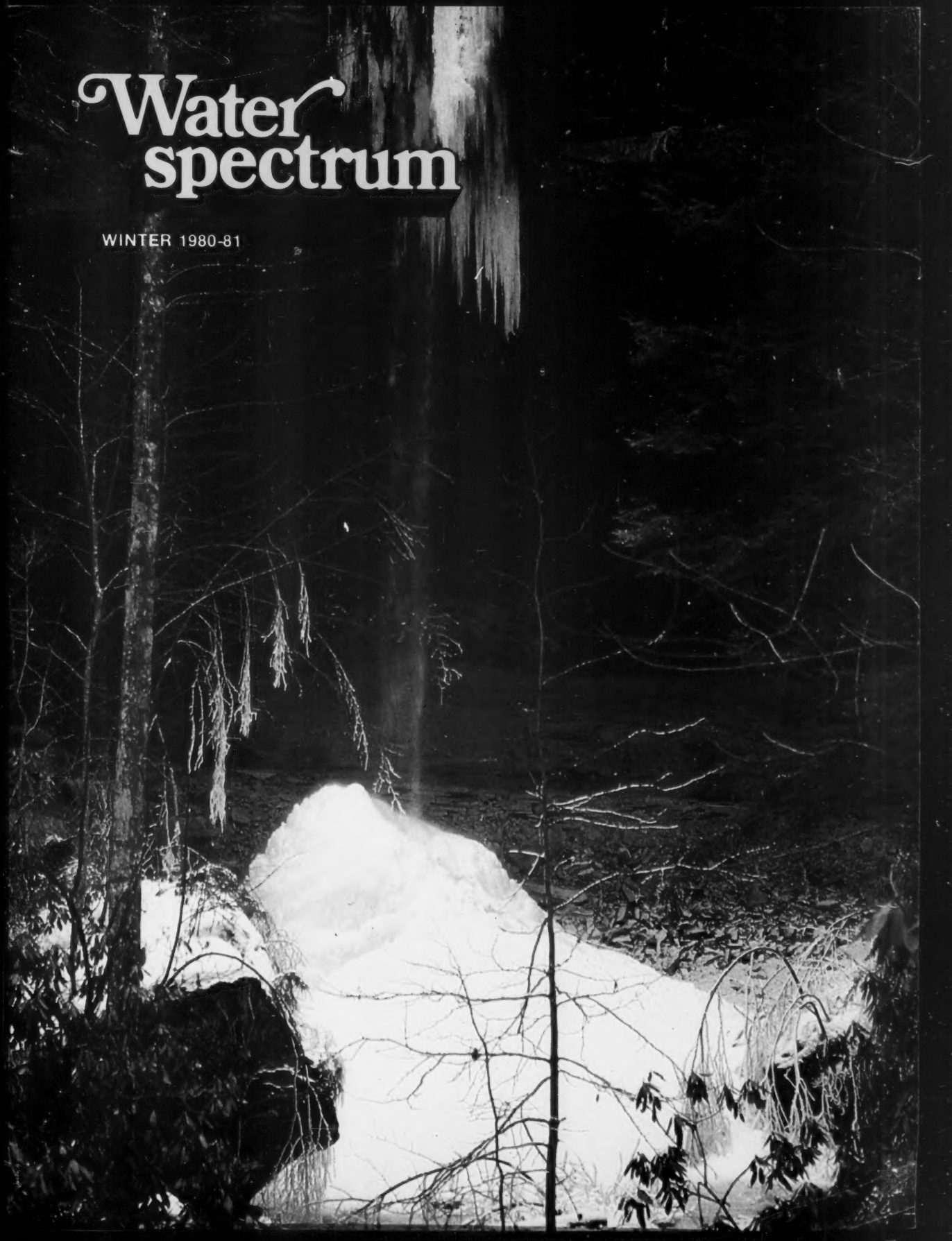
Water spectrum

WINTER 1980-81



Water spectrum

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Chief of Engineers Lt. Gen. Joseph K. Bratton

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Editor Bob Norton

Assistant Editor Vacant

Editorial Assistant Barbara Stevenson

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Editor, Water Spectrum
U.S. Army Corps of Engineers
Water Resources Support Center (WRSC)
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COVER: A winter scene in the Big South Fork National River and Recreation Area, Tennessee.

(Photo by Nashville District, Corps of Engineers.)

The Big South Fork Experience

by Susan E. Neff, Mark Bracher and Thomas J. Roth

It might be said that from Devils Jump Overlook a person can see forever. Viewing the river 460 feet below, one looks through millions of years and ages upon ages of laborious geological activity. Here within the compass of a single gaze are contained eons of interminable labor: First, the deposition of layer after layer of sediment by a primeval sea, a millimeter at a time until the shale and sandstone crust was over 100 meters thick; next, the receding of the sea and the evolution of the river, which began to dig its way back through the layers deposited by the sea, working, like the sea, a millimeter at a time and gradually carving out the rugged gorge; and finally, the emergence of life, halting and tentative at first, but with the same endless patience and perserverance of the sea and the river, eventually covering the area in living foliage from river to horizon.

This is the Big South Fork of Kentucky and Tennessee's Cumberland River, and these impressions are but a few of those that await the visitor to the Big South Fork National River and Recreation Area. Authorized by Congress in 1974, the National Area will have the dual purpose of preserving 123,000 acres of river and backcountry in its natural state, and of developing the recreational potential of the Area. The Big South Fork

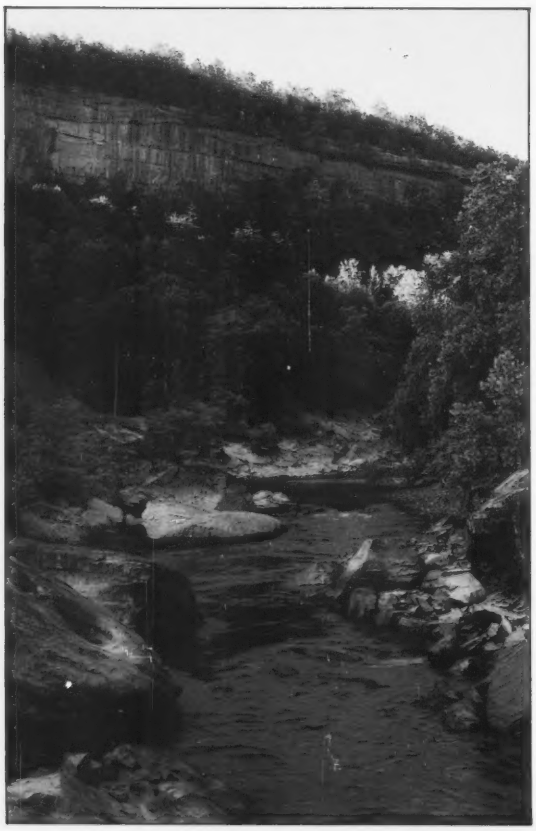
Ms. Neff is a landscape architect and Mr. Bracher was a writer/editor with Nashville District, U.S. Army Corps of Engineers. Mr. Roth is a landscape architect with the Ohio River Division of the Corps.

will be an important addition to the nation's public lands, for it will provide valuable recreational experiences for millions of people and preserve an important natural and cultural heritage.

BACKGROUND

In designating this National Area, Congress culminated several years of study — beginning with an 1881 Corps of Engineers recommendation for navigation improvements on the Big South Fork to more recent studies including a 1961 recommendation to build a hydropower dam at Devils Jump. An interagency report conducted by the Corps of Engineers and the Departments of Interior and Agriculture in 1968-70 studied several alternatives including reservoirs, scenic rivers, a national recreation area, national forest, national park, and possible acceleration of existing Federal, state and local programs. During the same period, the 1961 hydropower proposal was updated. The Water Resources Development Act of 1974 (Public Law 93-251) then directed the Corps to establish the National Area.

Once the Area is acquired and recreation facilities are completed, the Corps will transfer jurisdiction for operation and maintenance to the Secretary of the Interior who will administer the National Area through the National Park Service.



MASTER PLANNING PHILOSOPHY

A major step in the development of the Big South Fork was the recent completion of the Master Plan, which provides the foundation for all subsequent construction plans and specifications. The three primary elements of the plan include the design criteria, which set guidelines for the aesthetic and functional character of the facilities; the physical plan, which establishes the particular facilities and designates their location; and the management policies, which regulate use of the National Area.

Preparation of the Master Plan has been guided throughout by the realization that recreational value is determined not by the facilities or the type of activity per se, but rather by the restorative effect which the activity has on the individual. For the fundamental meaning of recreation is re-creation or restoration: recreation in the sense that creates one anew, making one somehow more alive and more human than before.

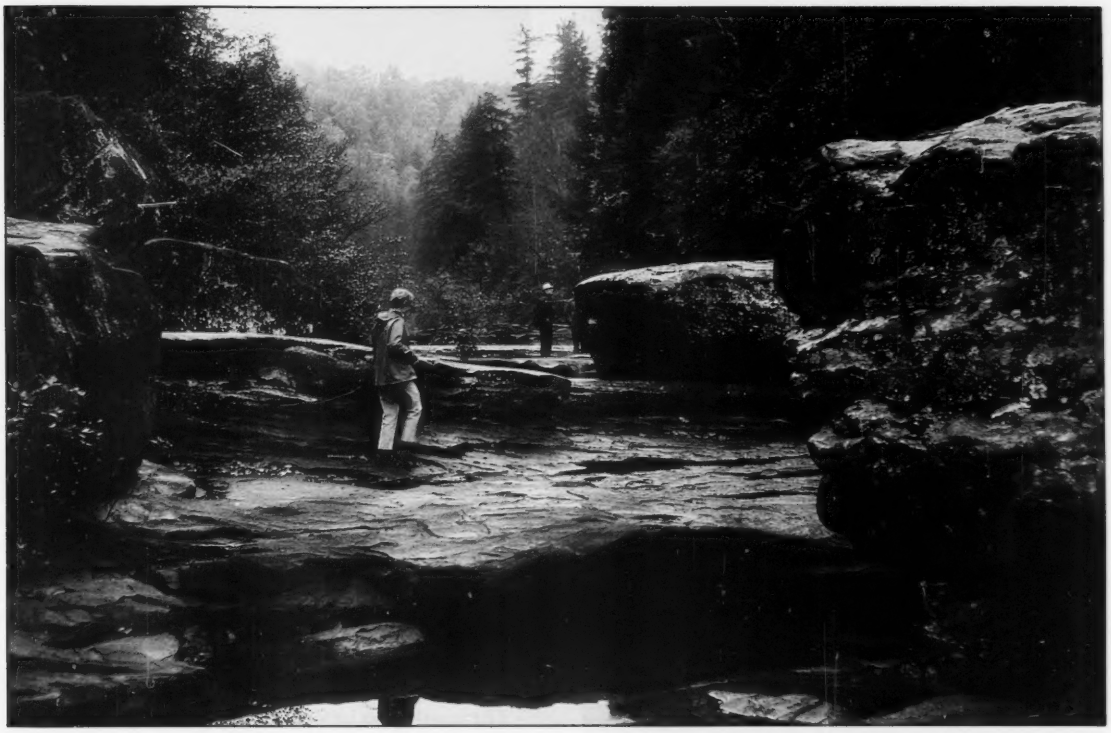
Since restorative recreational experiences are the raison d'etre of the development and the ultimate foundation of all the plans, these experiences must be clearly envisioned at the beginning of planning and recalled at every step of the subsequent design process. The only way to fully understand both the value of the total project and the reasons for the plans and design criteria presented in the Master Plan is to consider these experiences in detail.

PLANNING FOR RECREATIONAL EXPERIENCES

Sightseeing, in one form or another, will be the most common recreational experience at the Big South Fork. Virtually all of the estimated one million visitors each year will engage in sightseeing to a certain extent — even people such as canoeists, hunters and fishermen, who are primarily concerned with another activity, will absorb impressions from the area and be affected by them. All the resources and facilities of the project are thus in some way related to sightseeing. However, three overlooks will be established especially for sightseeing, each providing visitors with a magnificent view of the gorge and surrounding areas.

At the Devils Jump Overlook even the unreflective visitor will be impressed by the beauty of the scene: the rich foliage that in the summer covers the area in luxuriant green; the river, dark green like the trees, emerging from the wooded gorge on the left and quickly being swallowed up again on the right by the teeming vegetation; the smooth rippling water alternating with stretches of frothing rapids; the giant boulders strewn along the bed of the river. The steady sound of the rapids below, augmented by the intermittent rustling of the wind through the trees, can easily induce one into contemplation of the vast magnitudes of geological time and the amazing power and prolificness of nature's vital force.

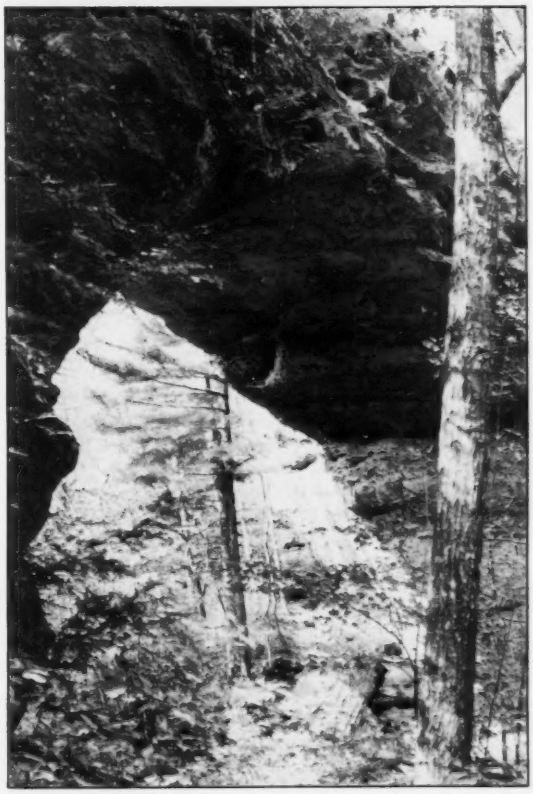
For visitors desiring a more extensive and intimate experience with nature, and for those who enjoy hiking, camping, horseback riding, or bicycling, an impressive trail system will provide 415 miles of different types of



trails. The entire system will be interconnected and will allow loop trips so that no retracing of steps will be necessary. Sites for backcountry camping will be designated on longer trails, and longer equestrian trails will have small horse camps near major campgrounds. The trails will provide a variety of experiences, passing through woods and fields and leading to fishing streams, historic places, geologic features, and gorge vistas.

One such trail will lead to Twin Arches, near the confluence of Charit and Station Camp Creeks. Sitting atop the arch high above the woods, one is able to take the long view — to detach oneself from everyday concerns and contemplate the marvelous abundance and interrelatedness of the things of nature. One can hear the wind as it rustles softly through the mass of trees below and then grows stronger, reaching the arch and causing a huckleberry to slap relentlessly against the sandstone. Above, a hawk catches the wind and soars majestically in the bright, rich sky, while farther down a swallow flits and darts through the breeze.

The arches themselves support an abundance of activity, which, although less obvious, is no less impressive than the flight of the hawk. At one end of the arches, a grizzled, twisted pine, no more than 4 feet tall, struggles silently and motionlessly out and upward from the rock — life emerging from lifeless matter. Its dead and broken limbs bear silent witness to frustrated attempts to transcend its dwarfish existence. At its tip, new needles and small cones give assurance that the effort continues, and the shedding of old bark gives proof of success.

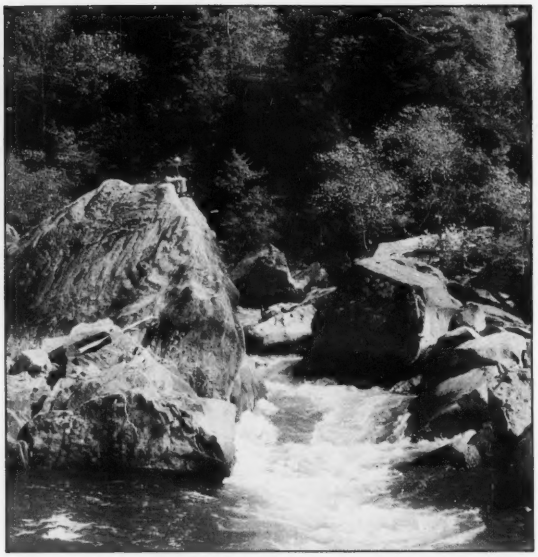


When one has the opportunity to immediately observe such phenomena and the time to contemplate them, one comes to realize the beauty and value of each thing. All living things reveal themselves as emanations of a single vital force pervading all of nature; even apparently lifeless matter like rock reveals itself to have some kinship with life. Opportunities for such realization abound on the trails of the National Area, and the trails are designed to foster such experiences.

Not everyone, of course, will have the precise realization outlined here; in most cases, the value and unity of all things will probably be experienced more as a vague feeling than as a clearly articulated thought. Yet the effect will be much the same for all who are attentive on the trails: an experience of renewal, deriving from the feeling that the world is somehow more interesting, more beautiful, or more valuable than before. Such reconciliation is perhaps the ultimate recreation, putting an end to the separation and opposition that a person often feels toward the world, and restoring one to that state of wholeness in which one communicates and participates with all other things.

A somewhat different recreational experience is provided by canoeing, although canoeists will also be sightseers and trail users. Engaged in hand to hand combat with powerful rapids, the canoeist experiences the fragility and tenuousness of his own being and gains a feeling of his ephemeral position — like the froth on the water — within the totality of nature. At the same time, though, he experiences a heightened sense of vitality, in the surge of energy with which he successfully confronts the water. Whipping and gliding through the rapids, the canoeist thus gains an intense experience of his own vitality and that of nature — and perhaps of their unity as well.

On the Big South Fork, canoeists can prove themselves against such rapids as the Washing Machine, the Rock Garden, Rion's Eddy, Jake's Hole, Bertha's Bump, Devils Jump, and Angel Falls. In all, there are about 80 miles of prime canoeing water within the National Area, with a wide variety of trips possible, ranging from easy floats to violent whitewater runs in



wilderness surroundings. Many single-day trips are possible, while for those who enjoy canoe camping, the run from Leatherwood Ford to Blue Heron Mine provides one of the finest overnight trips to be found anywhere in a wild gorge setting.

There will also be opportunities for fishing, boating and hunting in the National Area. Boat fishing is especially popular near Alum Ford in the spring. While powerboats will be prohibited upstream from Devils Jump, boat launching ramps will be provided at two locations downstream. Shore fishing will occur wherever people can gain access to the river. Water, restrooms, and parking areas will be available nearby. Hunting is traditional in the area and will continue; however, restrictions imposed on off-the-road vehicles will apply to hunters.

These and other activities will be supported by various types of campgrounds, which will accommodate the majority of overnight visitors. One campground will be especially (although not exclusively) for hunters, one for horsemen, and one for boaters and fishermen. Two group camps are planned, and there will be four large campgrounds with developed areas for recreational vehicles and improved areas for tents and trailers. And for those seeking peace and isolation, backcountry camping will offer the opportunity to experience the wilderness in solitude.

DESIGN CRITERIA AND INTERPRETATION

The ultimate goal in formulating all elements of the Master Plan has been to allow visitors the fullest and most varied experience of this impressive gorge and its surroundings, keeping intervention and development in the area as low as the requirements of health and safety permit. All aspects of design are required to be aesthetically and functionally compatible with the natural and cultural context and to reveal and interpret

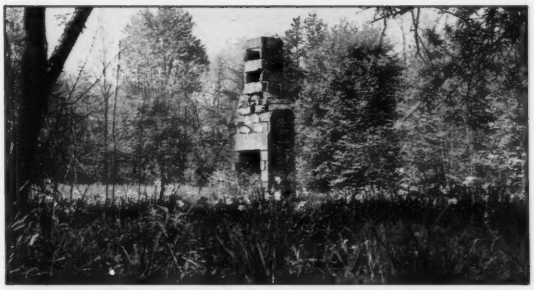
the intrinsic qualities of materials and places rather than to mask, disguise, or destroy them. Facilities will therefore be constructed of materials indigenous to the area (wood and sandstone), and these materials will be left unfinished wherever possible, to reveal their intrinsic character and to make explicit the connection between the natural material and its cultural function.

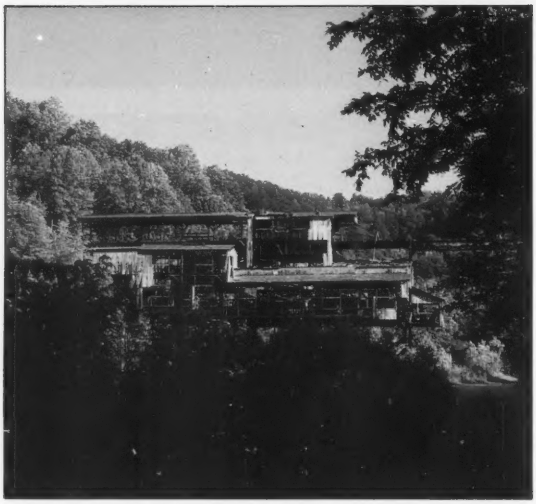
All recreational activities, and the facilities that support them, eventually will be under the management of the National Park Service, and an important part of the management task will be an interpretive program designed to expand and intensify visitors' recreational experiences. Opportunities abound in the Area for discovering scenic, geologic, ecologic, and cultural values; interest in these values will be stirred and understanding enhanced by pamphlets, exhibits, guided walks, and interpretive signs.

At overlooks, for example, the larger perspective invites an explanation of the geologic foundation of the area, the high sandstone bluffs speaking of the river's millions of years of erosive activity. Additional interpretation of the geologic structure will occur in conjunction with the arches, chimneys, and rock shelters encountered on the trails. The bountiful vegetation and wildlife of the area will also be described and explained.

Rock shelters will be used to describe prehistoric Indian occupation, which is evidenced by the remains of pottery and tools found in the soil on the shelter floors. Old chimney remains will be used to tell of early Euro-American hunters, trappers, and subsistence farmers who built cabins and wrested a living from the deep gorges of No Business and Station Camp Creeks.

Located adjacent to the National Area is Rugby, Tennessee, a National Historic District exhibiting the high peaked roofs, gabled windows, and decorative millwork of the Victorian era. The existing public tour and information program sponsored by the Rugby





Restoration Association will provide interpretation for visitors, and a proposed country inn, built in the fashion of Rugby's old Tabard Inn (destroyed by fire), will offer visitors a first-hand experience of this living historic colony.

The late 19th and early 20th century emphasis on the timber and mining industries will be featured at Zenith, Worley, and most extensively at Blue Heron. The Blue Heron coal tipple will be partially restored, and the coal mining community will be interpreted to create an understanding of early extractive industries. (Plans for both the Tabard Inn at Rugby and the restoration of the Blue Heron mine community are continuing beyond the Master Plan, and will become appendices to it when complete.)

Visitors to the Big South Fork, then, will have the opportunity to experience part of its rich heritage of natural and cultural activity, and to witness the relation of natural elements to each other and of cultural elements to nature. They will see how geologic activity has shaped the gorge valley and steep bluffs, and they will become aware of how centuries of human occupation have altered the area — cutting the virgin timber, mining the hidden coal, and farming the valleys. In a word, visitors will have the opportunity to achieve an ecological vision of things, in which everything has value and significance for everything else, and no action is without consequences.

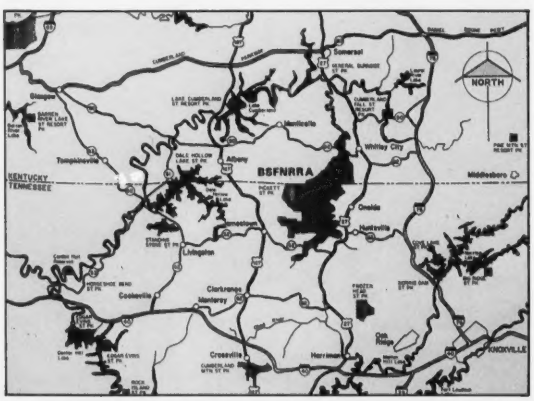
LOCATION AND SPINOFF OPPORTUNITIES

The many resources of the Big South Fork should provide significant benefits for great numbers of people. The Area is easily accessible to large urban population centers, extending from Columbus, Ohio, to Atlanta, Georgia. The wide distribution of 19 recreation sites throughout the 123,000 acres of wilderness will provide many opportunities for visitors to camp, canoe, or ride horses. The recreational opportunities are so numerous and varied that the Big South Fork cannot help but capture the hearts of its visitors, and the renewal their tired spirits experience is certain to entice them back.

The project's benefit to local communities will also be significant. En route to the Big South Fork, millions of visitors will pass through local commercial centers, helping to expand economic opportunities in the area. Two small lodges (at Bear Creek, Kentucky, and Rugby, Tennessee) will provide stimulus to surrounding areas to expand their lodging and dining facilities. In addition, campers will need supplies, vehicles will need gasoline, and cameras will need film, providing opportunities for other new or expanded commercial enterprises.

CORPS RECREATIONAL PLANNING — A 100-YEAR PRECEDENT

Finally, the project is significant for the Corps of Engineers as well. The dual objective of recreation and preservation represents a significant shift in focus for Corps recreation planning and has required unique sensitivity and imagination on the part of Corps planners. In virtually all of the previous multipurpose projects planned by the Corps, the primary endeavor involved the manipulation and transformation of natural resources, while preservation was incidental to the main concern. There is, of course, a precedent in the Corps for planning recreation in conjunction with preservation: one hundred years ago, the Corps suc-



cessfully developed a scenic roadway master plan for Yellowstone, the nation's first national park.

In authorizing the Corps to plan the Big South Fork National River and Recreation Area, Congress registered a vote of confidence in the Corps' ability to once again achieve a design that would preserve the environment while providing facilities to enhance its enjoyment. The Big South Fork Master Plan justifies that trust, and has preserved and augmented the legacy of sensibility and sensitivity established by the Yellowstone achievement.

The extent of consultation and investigation involved in the planning process, and the degree of detail resulting from it, made this plan one of the most comprehensive produced by Corps planners and elicits a high degree of confidence in the plan's quality and feasibility. In the two years spent preparing the plan, the natural resources were inventoried and analyzed, visitation patterns were projected, conceptual plans were drawn up and then reviewed in the field, public views were invited, revisions were made, and all steps were coordinated with the National Park Service.

These activities involved archeologists, architects, biologists, botanists, ecologists, engineers, historians, landscape architects, and planners. Much of this professional assistance was provided by the National Park Service and by the Landscape Architecture, Engineering, and Planning firm of Miller/Wihry/Lee, Inc.

In addition, community leaders and private citizens in Scott and Fentress Counties in Tennessee and McCreary County in Kentucky were interested and responsive during the development of the plan, and their thoughts influenced the plan in many ways. Environmental groups also gave support and constructive criticism, which were carefully considered in shaping the plan and the management policies.

The sense of excitement during the planning of the Big South Fork was comparable to what must have been felt during the planning for Yellowstone. Although mule teams have been replaced by four-wheel-drive vehicles, the discovery of a way down the bluff for a future trail or the location of an awe-inspiring view for a future overlook still elicited the feeling that a valuable discovery had been made that would be shared with millions of people. Corps planners have viewed their efforts as a contribution to the nation's welfare, for the Big South Fork project offers nothing less than the spiritual restoration of future Americans. As such, it constitutes a significant investment in the nation's future, and that, as a historian said of Yellowstone, is "the wonderful thing: that a hustling, restless dollar-chasing young nation ... should have been able to pause long enough to look into the future with such spiritual prudence ..." ■

EDITOR'S NOTE:

The Big South Fork National River and Recreation Area Master Plan has been published by the Nashville District. Copies will be distributed to the libraries of Corps Districts and Divisions.

by David Z. Piper

The oceans have served mankind for centuries as a means of transportation, as a source of food, and for recreation. During the past several decades the seabed of the continental shelf areas has provided us with petroleum to power our industries. Now mining companies have turned their attention toward the mineral deposits of the deep ocean, the sea floor beyond the continental margins. At depths greater than approximately 3500 meters, within the abyssal environment, are found manganese nodules which locally may totally cover the seafloor, but for the entire Pacific seafloor for example, probably average no more than 15 percent coverage.

The occurrence of these nodules on the seafloor has been known since they were first recovered by the British expedition of HMS Challenger in the mid-1870s. They remained scientific curiousities until 1965, when it was shown that their abundance on the seafloor and their elemental composition (primarily their content of nickel, copper and cobalt) made them a mineral deposit of potential economic worth. The initial estimate was that there were 1.5 trillion tons of nodules on the seafloor of the Pacific alone. This estimate has been greatly lowered with subsequent work and the amount of nodules which is actually mineable with today's technology and market represents perhaps only a small fraction of the total present. Even so, this deep ocean mineral deposit may represent a significant resource and may be mined within the next 15 to 20 years.

Mr. Piper is with the U.S. Geological Survey in Menlo Park, CA 94025.

Manganese nodules exhibit a variety of shapes, sizes, and textures.[1] Occasionally the shape reflects that of a nucleus, which may be any object found in the sediment such as a shark's tooth, a fragment of basaltic rock or lump of sediment, or a fragment of an older nodule. They may be spherical to highly irregular, but most commonly display a discoidal shape, regardless of the shape of the nucleus. Their size varies from a few millimeters in diameter to as much as 15-20 centimeters. Encrustations also occur on very large rock fragments such as pillow basalts, but these usually are not grouped with nodules, as the weight of the rock nucleus far exceeds that of the encrustation. The average nodule is approximately 3 to 3.5 centimeters in diameter.

Their surface texture may be smooth, granular or botryoidal (the form of a bunch of grapes). At any one locale, however, nodules have a rather uniform texture. For example, in the central North Pacific, nodules tend to have a smooth surface texture and usually are spherical to oblate. In the area of the Pacific between latitudes 5 and 15°N, nodules often are strongly discoidal. They have a smooth upper surface, where it is in contact with the overlying seawater and a granular to botryoidal girth and lower surface in contact with the sediment.

Their internal structure is characterized by concentric layers. Chemical, mineralogic and textural analysis of these layers has shed little light, however, into their origin. They may reflect episodic growth caused possibly by alternating periods of burial and exposure to seawater, reorientation or rolling of the nodule, or they may represent some internal recombination phenomena that occurs within an individual nodule. No success has been made in correlating these layers from one nodule to another, even for nodules from the same area. As nodules are several million years old, these layers have recorded aspects of the ancient abyssal environment. Future research may be able to unravel this record.

[1] *R.K. Sorem and R.H. Fewkes,* Manganese Nodules *(New York: Plenum, 1979).*

The major components of nodules are oxyhydroxides of manganese and iron, plus lesser amounts of the fine-grained components which make up the sediment associated with the nodules. Most of the elements in the periodic table have been found in nodules, but interest has focused on those metals that are strongly enriched in nodules relative to the surrounding sediment. Nickel, copper and cobalt average several tenths of a percent; lead, zinc, vanadium and molybdenum are present in the range of 10 to several 100 parts per million (ppm). The rare earth elements, such as iridium, for example, have concentrations of a few ppm to several 100 ppm. Gold, platinum and other noble metals are present at a few parts per billion to subparts per billion.

Nodule compositions vary rather strongly, however. Nodules from the Pacific tend to have higher concentrations of manganese, nickel and copper, and lower concentrations of iron, cerium and thorium than nodules from the Atlantic. Within the Pacific, nodules immediately north of the equator (between about 5° and 15°N) have nickel and copper values usually between 0.8 and 2 percent whereas in nodules from the central North Pacific these concentrations are less than about 0.5 percent. Thus, the discoidal

TREASURES FROM THE DEEP

nodules with granular to botryoidal surface textures have higher nickel and copper concentrations than the smooth, spherical nodules of the central North Pacific. The South Pacific has been studied much less than the North Pacific, but variations in nodule composition may mirror variations observed for the North Pacific.

The accretion rates of nodules have been measured by several independent radiometric and nonradiometric techniques[2]. The most plausible interpretation of these measurements requires that nodules grow only when at the surface and at rates of about 1 to 10 mm/10^6 years, or approximately one atomic layer per day. Thus, a nodule of average size commenced growing approximately three million years ago, or even longer ago if growth has been periodically interrupted, possibly by burial. This growth rate is about three orders of magnitude less than the accumulation rate of the surrounding fine-grained sediment. Thus, nodules remain at the surface of the seafloor for a period during which several meters of fine-grained sediment accumulate beneath them.

A casual glance at a map of the oceans (Fig. 1) suggests that nodules are rather randomly distributed in the deep ocean. Close examination, however, reveals that they tend to be restricted to areas where the accumulation rate of fine-grained sediment is less than approximately 10mm/1000 yr. As a result they are seldom observed along ocean margins, owing to the high influx of terrigenous debris (sediment derived directly from the destruction of rocks on the earth's surface), or on the seafloor underlying areas of high biological productivity, due to the high accumulation rate of biogenic debris (primarily the calcium-carbonate and opaline silica tests of planktonic organisms). These latter areas include the equatorial zone (the area within a few degrees of the equator), and the areas of the ocean at high latitude. Coastal areas, particularly along the western margins of continents, also exhibit high primary productivity and high accumulation rates on the seafloor of biogenic, as well as terrigenous, debris.

Nodules are most abundant in the Pacific and least abundant in the Atlantic, with the Indian Ocean hav-

[2] *J.L. Bischoff and D.Z. Piper,* Marine Geology and Oceanography of the Pacific Manganese Nodule Province *(New York: Plenum, 1979).*

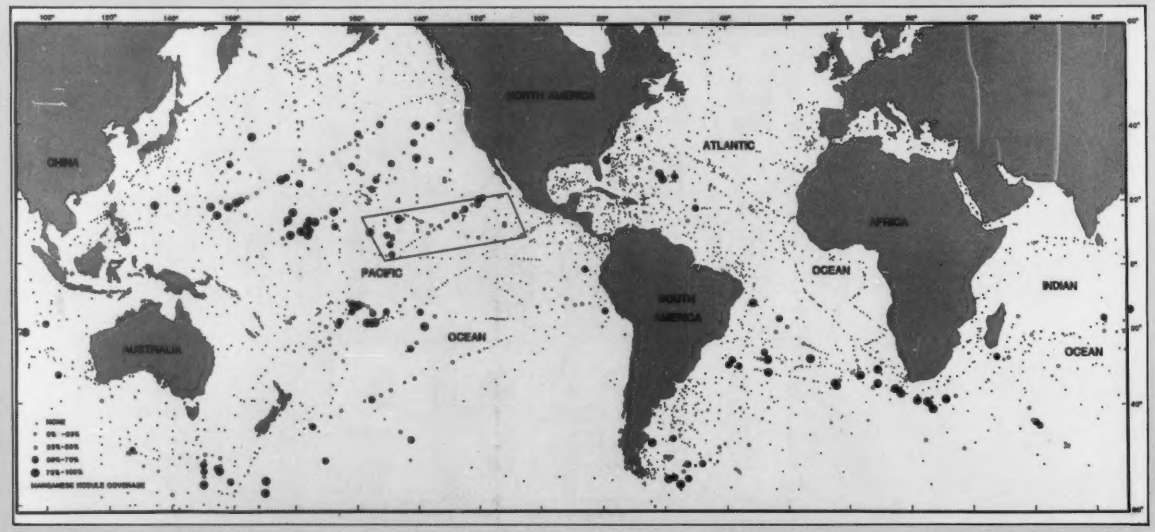


Fig. 1. *Locations of nodule occurrence, determined from bottom photographs. The enclosed area represents that portion of the ocean which is of prime interest to mining companies, due to high nodule grade and abundance. The numbers 1-8 give the location where nodules pictured in Fig. 2 were recovered. (From E. Ewing et al, Lamont-Doherty Geological Observatory, New York, 1971)*

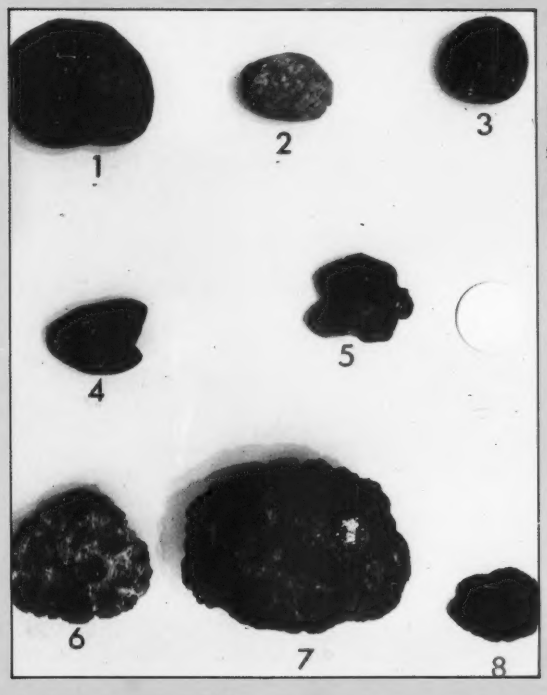


Fig. 2. *Nodules with differing surface texture. Nodules 1-5 are smooth; 4 and 5 also have an irregular shape. Nodules 6-8 have granular to botryoidal (grape-like) surface textures. The quarter is included to provide scale.*

ing an abundance intermediate between these two. Within the Pacific, two areas contain many large patches of relatively high nodule abundance, one in the central North Pacific and the other in the central South Pacific. The definition of the area in the South Pacific is highly uncertain, however, because of rather sparse sampling. Within the North Pacific, the area of high nodule abundance includes the area in which nodules have high nickel and copper contents; that is, the area between 5 and 15°N (See accompanying map).

The large scale variations of nodule properties have been revealed by examination of several thousand samples of the seafloor, collected since the Challenger Expedition by oceanographic institutes around the world. Intensive sampling of several areas in the equatorial North Pacific has revealed that the variability of nodule abundance, texture, and composition, exhibited on an ocean-wide scale, is present also on the scale of a few hundred meters. Within a single kilometer, nodule coverage may vary from 0 to 80 percent and large nodules (5 to 10cm in diameter) with granular or botryoidal texture and high nickel and copper contents may occasionally give way to small (1 to 4cm in diameter) smooth nodules relatively depleted in nickel and copper. Our unfamiliarity with mechanisms which might act to maintain such apparently different environments on this small scale in the deep ocean, for several million years (the time required for the nodules to attain their present size) has blunted attempts to mathematically or analytically model nodule growth in other than very general terms.

Nodules also exhibit a rather unexpected distribution within the sedimentary column. Although many sediment cores have collected nodules at depths within the uppermost few meters of sediment, approximately half of all nodules apparently are at the very surface of the seafloor[3]. This distribution becomes even more puzzling when we recall that nodules grow approximately 1000 times slower than the fine-grain sediment accumulates.

Research on nodules has attempted to address several of these questions of nodule genesis: (1) What is the source of metals in nodules; (2) What factors control the areal variations of nodule composition; (3) How are nodules kept at the surface of the seafloor and not buried by the "avalanche" of fine-grained sediment on which they rest; and (4) What controls areal variations of nodule abundance?

The National Science Foundation currently funds the MANOP Project, an interdisciplinary research project of scientists from throughout the United States who are attempting to design experiments which may provide answers to some of these questions.

The research to date strongly suggests that seawater is the immediate source for metals in nodules. Rivers and hydrothermal activity along oceanic spreading centers provide input to the oceans, but metals from these two sources are apparently well mixed

[3] *H.W. Menard,* Marine Geology of the Pacific, *(New York: McGraw-Hill, 1964).*

prior to their incorporation in nodules. Chemical reactions within surface sediments, or sediment diagenesis, also apparently have a strong influence on nodule composition. This is particularly true in those areas where there is a high flux of biogenic debris to the seafloor. The effects of these processes on nodule composition, and how they vary regionally, are currently poorly understood. One difficulty, among many others, is that the nodules represent a record of chemical reactions which has been ongoing for several million years. However, we are able to examine only today's seawater and surface sediment. For most nodule areas, this sediment is thought to be accumulating at the present time.

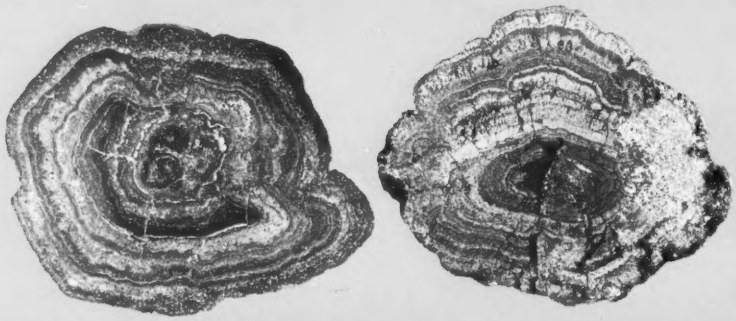


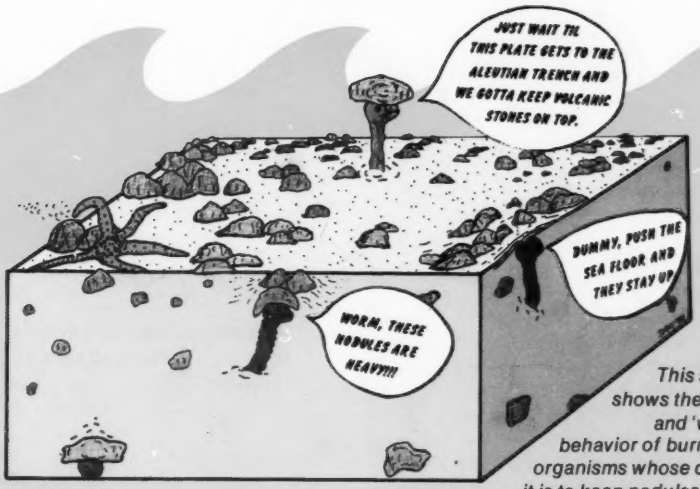
Fig. 3. *Cross sections of two nodules from the equatorial North Pacific. Each nodule is approximately 3.75 cm in diameter. The nucleus of both is a fragment of an older nodule, although this relation is not as clear for the nodule on the right. Both nodules exhibit concentric layering; for the left nodule the layers appear to be continuous and uniform, whereas for the right nodule the individual layers do not totally encircle the nucleus.*

The process or processes by which nodules are kept at the surface are even more of a mystery. (The areal distribution of nodules can be considered perhaps as merely a part of this problem; variations of nodule abundance at the seafloor may represent variations of success of this unknown process). As indicated by the literature on this subject, we have been hard-pressed to advance ideas which lend themselves to scientific inquiry, surely the most important criterion of any useful hypothesis. As noted earlier, nodules are growing at a rate 1000 times slower than the sediment on which they rest, or approximately 5 mm/10^6 yr. Radiometric analyses of nodule tops and bottoms further require that nodules maintain their orientation (i.e., they do not roll over) for as long as 500,000 years. Thus, as much as 5m of fine-granined sediment has been tucked under the average nodule during its total history and as much as 2.5m since its growth was last interrupted. The environment in which they grow is indeed tranquil.

The shape and internal texture of nodules show that they certainly roll over. Organisms living on the seafloor have been accused most often of being the culprits. They are usually viewed as lifting the nodules up or rolling them over in search of food and one another. Organisms large enough to roll nodules over certainly do dwell at these abyssal depths. Even if these organisms were inclined to roll nodules over, they could have nothing to do with keeping nodules at the surface. During the 500,000 years between flips, the nodule would have been buried under tens of centimeters of fine-grained sediment in the absence of other processes. We must assume that it is not the Force, or another power, which maintains nodules at the surface of the seafloor merely to confound us. Unfortunately, plausible explanations which are consistent with the meager amount of data have been in short supply.

I suggested recently that the organisms which burrow through the sediment, rather than the organisms which dwell on and above the seafloor, may be responsible for maintaining nodules at the surface; not an altogether new idea, I should add. The organisms are known to homogenize and leave mottled the upper few centimeters of sediment in their effort to glean from this material its small amount of organic matter. If they actually wedge through the sediment, beneath the surface veneer and nodules and fine sediment, and back-fill with that fine sediment which has recently arrived at the seafloor and which would otherwise soon bury nodules, then one can visualize how they may be lifting the entire seafloor. This mechanism might leave the nodules relatively undisturbed. The possible rationale for these organisms to preferentially ingest the most recent sediment is that it should have the highest concentration of labile organic matter. Not knowing the habits of such organisms, however, I am at a loss as to why they would not care to egest, or tuck, this sediment beneath the surface. This idea recently prompted one of my colleagues to put this notion in technicolor and 3-D, if

not stereophonic sound. As can be seen from one of the sketch's comments, my colleague has seen one additional problem which I overlooked. What a task these organisms will have when this parcel of seafloor moves into the Aleutian or some other trench owing to seafloor spreading.


JUST WAIT TIL THIS PLATE GETS TO THE ALEUTIAN TRENCH AND WE GOTTA KEEP VOLCANIC STONES ON TOP.
DUMMY, PUSH THE SEA FLOOR AND THEY STAY UP
WORM, THESE NODULES ARE HEAVY!!!

(David Howell)

Fig. 4. *This sketch shows the 'right' and 'wrong' behavior of burrowing organisms whose charge it is to keep nodules afloat.*

The mining companies are interested in a somewhat different set of questions. What is the abundance of nodules on the seafloor; where are the nodules of highest grade (i.e., highest nickel and copper concentrations); and how might they be most efficiently recovered and processed? The academic community provided the initial information on the first two of these questions. During the past 15 to 20 years, however, industry has ascertained much more thoroughly the metal reserves of deep ocean nodules. Unfortunately, their results are proprietary and our estimates are still based on a relatively small amount of data.

Two constraints limit considerably the area of the ocean that might be mined in the foreseeable future: nodule grade and nodule abundance. It is now widely accepted that first-generation mining will require a minimum average abundance of 5 kg/m^2. The nickel plus copper concentration must average no less than 1.75 percent. These figures limit the area of prime interest to approximately 2.2 million km^2, or less than 2 percent of the ocean floor — no small area even so. The largest single area that meets these requirements is in the equatorial North Pacific, from approximately 5 to 15°N and 120 to 155°W. This area corresponds to the region between the Clarion and the Clipperton Fracture Zones. It borders the zone of high primary productivity along the equator, but is within the area of the North Pacific where the rate of sedimentation is less than approximately 5mm/1000 yr.

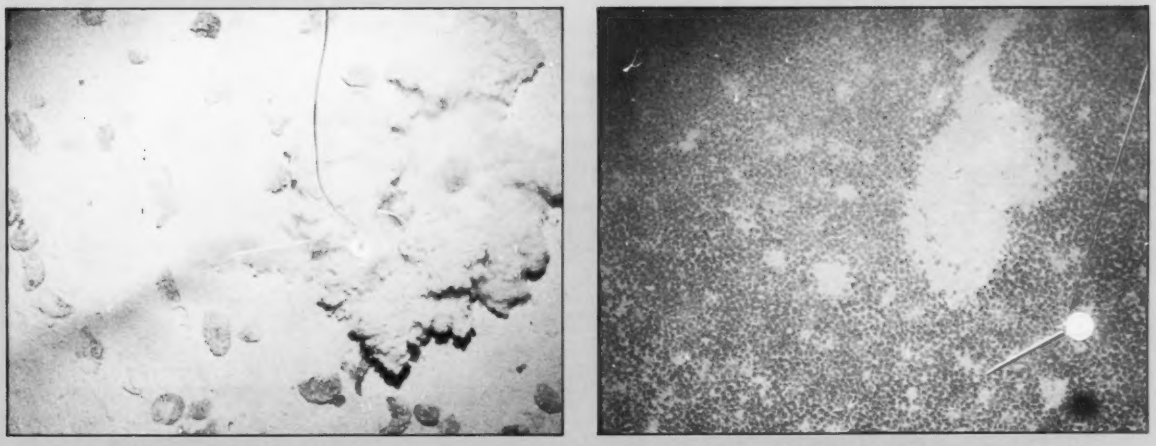


Fig. 5. *Two photographs of the seafloor taken at a depth of 4500 m, and within a kilometer of each other. The photo at left shows approximately 10 percent nodule coverage with an average diameter of 7 cm (the diameter of the compass face is 7.5 cm). In the photo at right the coverage is about 75 percent with an average diameter of 2.5 cm. The bare places are mounds formed by benthic organisms, which burrow through the sediment. The mounds appear to bury the nodules rather than displace them laterally.*

Several attempts have been made to estimate nodule reserves in the deep ocean using the constraints given above. The difficulty and uncertainties in any such estimate are caused not only by the variability of nodule composition and abundance on a scale that can be only poorly defined by our sampling, but also by such vagaries as the price of heavy metals on the open market.

A. A. Archer has recently summarized the several estimates of nodule potential (See Table 1). He has even gone one step farther, to give us an estimate of future resources. In the future, nodules of lower grade and abundance will likely be mined owing to improvements in recovery and processing techniques. Archer's estimates of this future resource for the four metals of primary interest (nickel, copper, cobalt and manganese) are indeed quite significant when compared to the estimate of current land reserves.

The effect on the environment of mining is difficult to evaluate. Preliminary work by the DOMES Project (the Deep Ocean Mining Environmental Study coordinated and funded by the National Ocean and Atmospheric Administration) suggests, however, that the effect of deep ocean mining on the oceanic (open ocean) community may be slight; but somewhat greater on the benthic (seafloor) community. It is not known presently how resilient this benthic community might be to burial by sediment suspended during mining. Some groups of organisms will thrive while others obviously will do less well. Certainly this environment needs to be closely watched during any mining operation in order to monitor possible changes in the biological community of this presently poorly understood region.

TABLE 1

Reserves and Resources of Metals in Manganese Nodules Compared with Known Reserves on Land.

These estimates, by Archer, are intended to be just that, as future work will surely require their re-evaluation.

	Ocean		Land
	Potential Reserves	**Future Resources**	**Proven Reserves**
Assumed minimum grade (N%Ni + Cu)	1.76%	0.88%	
Average grade (%Ni + Cu)	2.29%	1.57%	
Assumed minimum abundance (wet kg/m²)	5.	2.5	
Assumed average nodule diameter[2] (cm)	3.68	3.68	
Average abundance (wet kg/m²)	15.	13.5	
Estimated area with this grade and abundance (wet kg/m²)	2.2[1]	18.5	
Total nodules (wet million tons)[4]	33,000	250,000	
Total nodules (dry million tons)[4]	23,000	175,000	
Assumed average Ni grade	1.26%	0.86%	
Ni content (million tons)[3]	290	1,500	54
Assumed average Cu grade	1.03%	0.71%	
Cu content (million tons)[3]	240	1,240	460
Assumed average Co grade	0.25%	?	
Co content (million tons)[3]	60	?	1.5
Assumed average Mn grade	27.5	?	
Mn content (million tons)[3]	6,000	?	2,000

[1] *The total area seems to be close to 2.2 (possibly somewhat conservative — my evaluation).*
[2] *All tonnages will be less if the average diameter of the nodules is less than 3.68 cm (1.45 in): for example, they would be reduced by about 30% if the average diameter is 2.54 cm (1 in.)*
[3] *Maximum quantities* in situ *rounded to nearest 10 million tons (manganese rounded to nearest billion (10^9)): recoverable metal would be substantially less.*
[4] *Rounded to nearest billion (10^9).*

Thus, we can say that seafloor nodules contain significant reserves of the four metals previously mentioned, and perhaps others. The possible environmental impact, although not fully known, does not appear to be so great as to preclude mining. Several mining companies have demonstrated the technical capability for recovering nodules

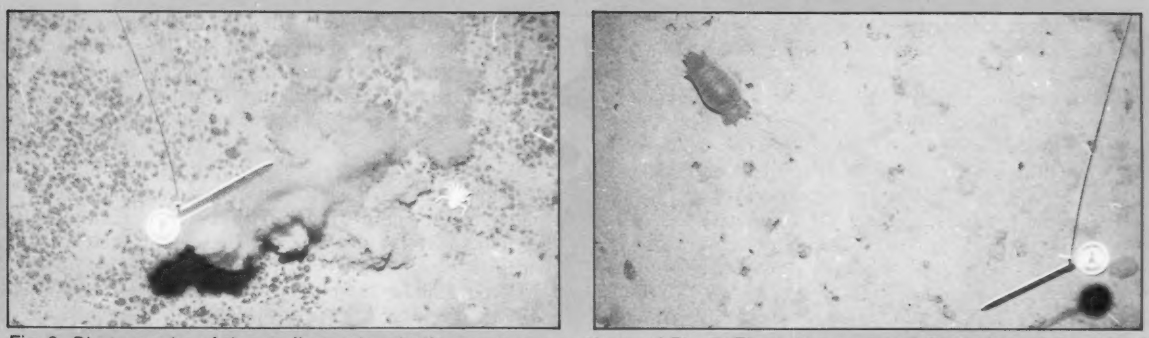


Fig. 6. *Photographs of the seafloor taken in the same area as those of Fig. 5. They show some of the variety of the animal life which lives on and near the seafloor at abyssal depths.*

from depths as great as 5000m. Exploitation of this deposit is now hindered more by the lack of an international legal structure, allowing for recognition of mine sites and exploitation rights, than by any other factor. The United Nations Conference on Law of the Sea has debated the issue of deepsea mining since the General Assembly declared these deposits to be the "common heritage of mankind". Although these debates have been characterized by the inability of member nations to reach some accord on this issue, agreement seems likely to come within the next few months.

The ocean floor possesses other mineral treasures, in addition to manganese nodules, which someday may also prove to be of more than academic interest. Phosphorite concretions are known to occur on the continental shelf and slope of many countries where upwelling of nutrient-rich water supports a large population of planktonic organisms. The accumulation of organic detritus apparently has provided a flux of phosphorus to the seafloor in these areas that has supported phosphorite accretion in the past, if not currently.

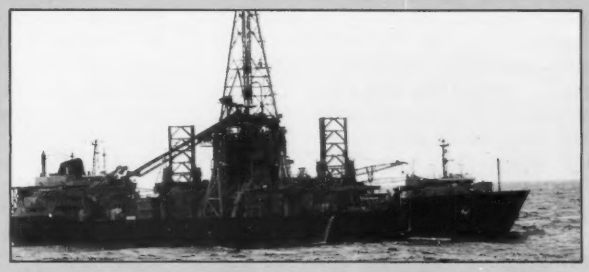


Fig. 7. *The mining ship GLOMAR EXPLORER.*

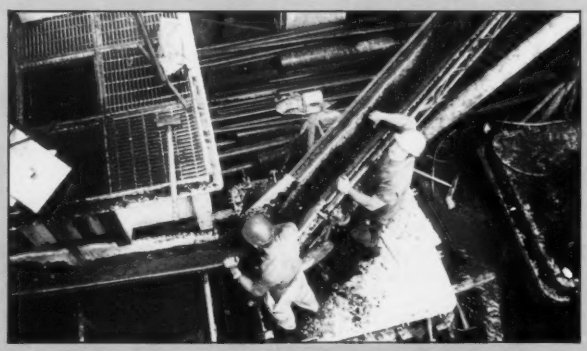


Fig. 8. *Nodules come aboard the GLOMAR EXPLORER after having been lifted from the seafloor through 5200 m of steel pipe.*

At several sites along the East Pacific Rise and also in the Red Sea, hydrothermal metal deposits have been observed. They are thought to be forming as a result of present-day seafloor spreading of the earth's crust. These deposits are certainly as intriguing as manganese nodules and deserving of discussion. ■

The Future of

by Rexford B. Sherman

America's ports play a crucial role in the movement of energy commodities. Most of our imported petroleum and an increasing proportion of our natural gas supplies are delivered by ocean carrier. Efficient ports are essential for our expanding coal export trade. These vast tonnages, so essential to the national well-being of the United States and to its economic and strategic interests, depend heavily on the availability of a modern and highly efficient port system.

At present, the United States is served by more than 200 deep draft ports located along its three seacoasts (including Hawaii, Alaska, Puerto Rico, and the Virgin Islands) and on the Great Lakes. Our nation's port system has developed almost entirely as a result of state, local and private initiative. Port authorities are organized and administered as divisions of state and local governments. Between 1946 and 1978, approximately $5 billion was invested in the construction and modernization of port terminal facilities. In the 1973-1978 period alone, U.S. ports spent approximately $1.6 billion to expand and improve marine terminal capacities.

The U.S. Maritime Administration projects that port development expenditures between 1978 and 1983 will total $3.4 billion — a firm indication of the port industry's commitment to meet the needs of U.S. waterborne commerce. And while the bulk facilities that serve the energy trades have generally been the product of private investment, the public port agencies, individually and collectively, can do much to ensure the success of these endeavors.

Looking to the future always entails certain risks. Even the most sophisticated projections of tonnage growth and facility requirements are by necessity tentative and likely to go far of the mark as a consequence of unforeseen developments. We have seen this happen repeatedly during the past decade. The Arab-Israeli War of 1973, the sudden emergence of OPEC as a major world economic force, and more recently, the Iranian Revolution and the Soviet invasion of Afghanistan have all had seriously traumatic impacts on world trade, the movement of energy commodities and world economic and political conditions in general. Uncertainties as to the availability of foreign energy supplies are bound to affect energy planning in all industrial nations.

Nevertheless, it would appear that major trends are emerging that will almost certainly have a significant impact on the energy trades and, as a consequence, on the United States port system. These conditions must necessarily weigh heavily in any decision-making relating to port facility development. The U.S. is certain to continue importing large quantities of crude oil and petroleum products over the remainder of the century but at a decreasing rate. During the first half of 1980, U.S. oil imports, both crude and refined, have been running well below the 8 million barrel per day limit set by President Carter, and significantly below those of a year ago. How permanent this trend will be remains to be seen — but the certainty of higher OPEC prices, the effects of conservation measures and increasing reliance on coal, nuclear, synthetic and other non-oil energy sources are sure to have a restraining effect on oil imports in the future.

What this suggests is a reduced requirement for expanded oil receiving terminals at our ports. While some expansion may occur on a regional level, along with necessary modernization and rehabilitation of existing facilities, it appears unlikely — given the uncertainty that clouds the future of crude supplies — that any major investment nationwide will be made in additional or greatly expanded waterside oil receiving terminals.

For imported liquified natural gases (LNG), the future also seems clouded and fraught with uncertainty. A recent study by the U.S. Office of Technology Assessment (OTA) states that U.S. imports of LNG could rise from the currently approved level of 0.8 trillion cubic feet to between 1.3 and 1.8 tcf by the mid-1990s. Eleven LNG ships are now active in the U.S. trades; seven are under construction at U.S. yards; and the National Transportation Policy Study Commission projects in its medium growth scenario that the total could rise to 58 ships by 1990 and 82 by the year

Mr. Sherman is a research coordinator with the American Association of Port Authorities, 1612 K Street, N.W., Washington, D.C. 20006.

Baltimore harbor. (CofE photos)

U.S. Energy Ports

2000. But as of now, only four LNG terminals are operational — three importing terminals at Everett, MA; Cove Point, MD; and Elba Island, GA, and a loading terminal at Kenai, Alaska, through which LNG is being exported to Japan. A fourth receiving terminal is under construction at Lake Charles, LA, and will probably begin receiving LNG in early 1981. A fifth — to be located near Oxnard, CA — designed to receive LNG from Indonesia and Alaska — has cleared the permitting hurdles but is now being challenged in court. A number of other LNG terminal proposals have yet to advance beyond the talking stage.

Problems with LNG arise from the heavy capital investment in ships and loading and receiving terminals, safety considerations, and supply availability. The OTA study, for example, predicts that $5 billion in capital investment would be required for a single "world scale" LNG venture in the early to mid-1980s, of which 40 percent would be for gas production and liquification facilities in the exporting nation, 40 percent for the ships, and 20 percent for the import terminal and revaporization facilities in the United States. Even if the safety issue were resolved, the question of supply, price, and, most importantly, investor confidence would remain. Furthermore, past U.S. energy policy and the lengthy delays entailed in the permitting process and fending off legal challenges have been major impediments to LNG terminal development.

The major suppliers — Algeria, Indonesia, Nigeria and the Middle Eastern states — all of them OPEC members — are insisting that the prices of their gas should be linked to the price of petroleum. The rapid escalation of OPEC oil prices and periodic threats to shut off supplies to the West should caution us against developing a similar dependence on these same nations for gas supplies. These circumstances are almost certain to make potential investors wary of committing large amounts of new capital to new LNG transportation systems, including of course, any receiving terminals that might be sited in the U.S. Moreover, importing LNG can only exacerbate this country's balance of payments problem.

The future of coal in U.S. foreign trade shines brightly in contrast with the rather negative outlook for oil and natural gas. The major western industrial nations, including the U.S., have expressed rather firm determination to turn to coal as an important solution to their energy needs.

Here in the United States, the Federal government has taken definite steps to restrict and, ultimately, to sharply curtail the use of petroleum and natural gas in electrical generating and industrial powerplants. The Powerplant and Industrial Fuel Use Act of 1978 (P.L. 95-620) specifically calls for "the expanded use, con-

Ore unloading piers at Philadelphia harbor.

sistent with applicable environmental requirements, of coal and other alternate fuels as primary energy sources for existing and new electric powerplants and major fuel-burning installations." Given the continuing controversy over nuclear power and the unlikelihood that solar, thermonuclear and other energy alternatives will be able to contribute significantly for many years to come, coal use is almost certain to emerge as the most practical near term answer to America's energy problem.

U.S. coal output totalled 770 million tons in 1979; it is predicted that it will exceed 2.2 billion tons by the year 2000. Twenty years from now, coal may account for 33 percent of the nation's energy supply, compared to 19 percent at present. Oil's share, by contrast, is projected to drop from 46 to 32 percent, and gas from 26 to 17 percent.[1]

The escalating price of oil and natural gas and the likelihood that OPEC nations may curtail or even cut off supplies have given Japan and Western Europe reasons even more compelling than our own to seek out alternative energy sources. In May 1979, the 20 industrial nations in the International Energy Agency (IEA) agreed to increase their use of coal by converting oil-fired plants and constructing new coal burning facilities. Similar pledges were made at the Tokyo economic summit in June 1979 and more recently at the Venice summit at which the participants agreed to double their coal production and use "by early 1990." The IEA has estimated that the demand of the 24 nations comprising the Organization of Economic Cooperation and Development (OECD) could rise from the 591 million metric tons consumed in 1976 to 1.124 billion metric tons by the year 2000.

The World Coal Study, *Coal — Bridge to the Future*, published last May, concludes that coal will be required to meet half of the OECD's anticipated increase in energy needs over the remainder of the century. Substantial growth in coal use is also predicted for the developing countries (most significantly India) and the so-called Centrally Planned Economies, especially the Soviet Union and the Peoples Republic of China. South Africa, which possesses extensive coal reserves, has invested heavily in coal-based synthetic fuel facilities and derives 75 percent of its fuel supply from that source, according to the Coal Study. South Africa's example may very well be precedent for a massive conversion to coal energy by other advanced industrial nations.

[1]*Exxon Company, USA.* Energy Outlook 1980-2000, *Dec. 1979.*

Coal is vital to the nation's energy-sufficient future.

That would mean an unprecedented demand for American coal on the world market. The U.S. Department of Energy has conservatively estimated that U.S. steam coal exports for electrical power generation could reach 80 to 100 million short tons by 1990, and thereby create 38,000 new jobs for coal miners and another 190,000 new jobs in coal mining communities.

Already a semblance of that future is taking form. The Japanese are now active in the market and have indicated their import requirements could rise from the level of one million tons per year to 53 million tons annually by 1990 and 80 million tons by 1995. Other nations that have entered the market or have expressed active interest in steam coal are France, Italy, Great Britain, West Germany, Sweden, Denmark, and Brazil. The United States is in a strong position to make the most of this tremendous opportunity. It has the largest and most varied reserves of quality coals available anywhere in the world. Furthermore, no other nation can match the efficiency of the U.S. coal mining industry. While inland transportation rates, particularly where rail is the only alternative, are high and sometimes undercut the competitiveness of U.S. coal even

on domestic markets, the facts are nevertheless that in recent months, thanks in particular to favorable ocean shipping rates, U.S. coal has been landed in Europe at prices below those charged for competing coals from South Africa and Australia.

The United States is currently the world's leading coal exporter, although Australia, South Africa, Canada, and Poland are becoming very formidable competitors. A dramatic rise in U.S. steam coal exports would create many new jobs, not only in coal communities, but in the transportation, equipment, and all other industries that serve the coal industry. Coal export growth could make an impressive contribution to gross national product, national income, and to the U.S. balance of payments. Coal exports to Japan, for example, could go a long way in helping to correct America's negative balance of trade with that country.

The potential is there, but there are also significant problems. Despite evidence of a trend, massive conversion to coal use on a world scale is by no means a foregone conclusion. Nor is there any guarantee that the United States will be able to take full advantage of the opportunity as it emerges. Among the constraints underscored by the IEA are present leasing schedules, environmental problems, current fiscal regimes, essential investment initiatives, and limits on transport capacity. Most important, however, as the IEA goes on to state, "The principal impediment appears to be a failure on the part of many private and public energy planners to appreciate the growing economic attractiveness of using coal instead of oil."

There lies the key. Coal, to be competitive, must offer a significant cost advantage over alternative fuels before large scale conversion will occur. The transportation industry, ports and carriers alike, have a very real interest in ensuring that coal maintains a strong competitive position versus other energy commodities. And the United States must ensure that American coal retains its primacy on the world market.

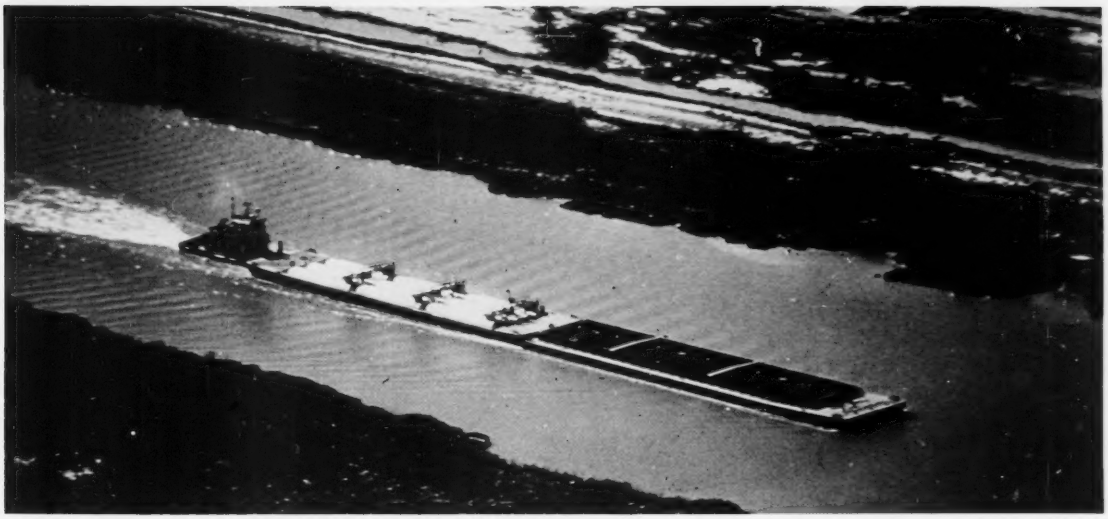
Ports are a critical factor in the movement of coal, as well as ores, grains and petroleum products. The capacity of a port to receive large coal vessels, load, and turn them around without excessive delays has a major bearing on the competitiveness of coal on overseas markets. Vessel delays, for whatever reason, are costly to shippers and turn business to competitors. Thus, ports must be dredged adequately to accommodate vessels of requisite drafts and possess docks and equipment needed to load them quickly and send them on their way. Also critical is the port interface with the inland carriers, particularly railroads and barges, to ensure that coal arrives at the port in a timely fashion and can be readily moved to dockside without preventable interruption in the flow.

At present, U.S. ports equipped to serve the overseas coal trade are concentrated largely on the East Coast at Philadelphia, Baltimore, and Hampton Roads. Smaller, though highly efficient terminals are located along the Gulf Coast at Mobile and the lower Mississippi. Very limited capacity exists on the Pacific Coast. While a number of major coal loading facilities are located on the Great Lakes, the size and draft limitations imposed by the St. Lawrence Seaway and the Welland Canal effectively exclude their use by large, ocean-going coal ships, making it unlikely that they could ever, or at least in the foreseeable future, play much of a role in the overseas coal trade.

The current loading capacity of U.S. coal piers on the Atlantic and Gulf Coast ports have been set at about 118.1 million tons per year. Planned expansion of existing terminals and the proposed construction of new terminals could raise that to perhaps 126 million tons per year. With current overseas exports averaging about 50 million tons, that, at first glance, would seem entirely adequate. But if world demand expands as rapidly as some predict, that capacity could be quickly exhausted within the next decade.

The hopper dredge Biddle *is part of the Corps of Engineers minimum dredging fleet.*

The facts are that a number of these facilities, particularly at Hampton Roads, which accounts for some 70 percent of all U.S. overseas coal movements, have been subject to recurrent criticism of vessel congestion with as many as 30 ships swinging at anchor awaiting



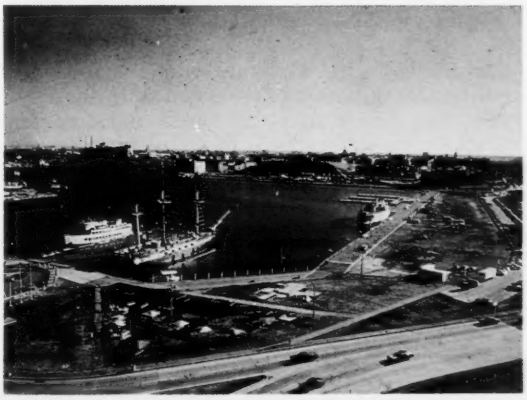
A combination coal and oil tow on the inland waterway system.

their turn at the coal berths. Foreign buyers are expressing skepticism as to the ability of U.S. ports to turn their ships around, and complain that costs incurred due to the long delays of coal ships at anchorage have become extremely costly to them. Unless a solution is found, our foreign customers may very well go elsewhere for their coal.

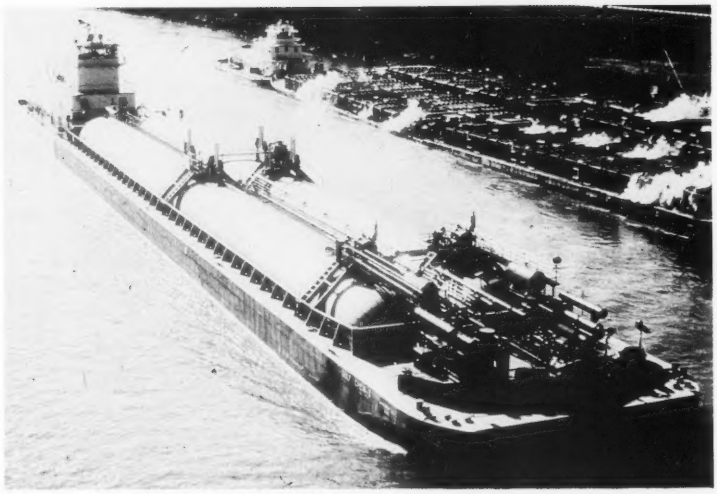
One partial solution, perhaps, would be to provide coal loading facilities for domestic coastwise trade separate from those serving the export traffic. Still another might be the development of entirely new coal ports perhaps in the Hudson or Delaware rivers or in the South Atlantic port range. Dredging berths and access channels to greater depths and the construction of offshore loading terminals could, in some instances, meet the needs of the large, deepdraft bulkers (ranging up to 250,000 deadweight tons with drafts of 60 feet or more) that are almost certain to be employed in the coal trades in the future.

There is a particular need for major coal exporting terminals on the West Coast that would allow foreign customers, particularly Japan and other nations on the Asian rim, to take advantage of the massive deposits of low-sulfur bituminous coal that underlie our western states. Puget Sound, where channel and harbor depths reach over 65 feet, would be ideal. Other sites near the mouth of the Columbia River or off the coast of California might also meet the need.

If the United States wants to export coal, it must be prepared to offer foreign users opportunities even more attractive than those offered elsewhere. For one thing, it should try to attract foreign investment. It should ensure that U.S. ports are fully capable of moving coal at least as efficiently as their overseas competitors. Every interest involved — the coal operators, the carriers, the



Baltimore harbor will figure prominently in America's energy needs forecasting.



A liquid natural gas barge.

Federal government, and, most certainly, our public port agencies — should unite in working out a policy that will ensure foreign customers that their needs are better met here than elsewhere.

Until recently, few public port agencies have paid much attention to the bulk trades. Waterside coal terminals were, for the most part, owned and operated by railroads and other private operators. The port agencies left all matters relating to the handling and shipping of coal to the shippers and carriers. But with coal promising to become of rapidly growing significance in U.S. port traffic, it is clear that this attitude should change. The ports should take more an active role.

For example, they could work with the shippers, the inland carriers, and the shipping interests in planning future facility needs, and reaching solutions aimed at assuring the smooth flow of coal and vessel traffic. As in the past, they would act as sponsors for deep-draft navigation projects required to accommodate colliers and other ship traffic. They could also prevent local opposition, including any from environmentalists, by educating the public and keeping it informed as to the need for coal terminals. Moreover, particularly in view of the generally weakened financial state of the nation's rail carriers, the port agencies themselves might well find it profitable to invest in and even operate coal facilities on their own. Overall, more active involvement of the public port agencies in coal terminal development and operation would help ensure that the necessary planning would reflect a broader public purpose, avoid wasteful duplication, allow access to public credit, and, hopefully gain wider public acceptance of the need.

The Federal government also has a key role to play, but, as we all know, the government tends to speak in conflicting voices — with the result it frequently undercuts and even negates the success of highly laudable and worthwhile objectives. The Carter Administration committed itself to promoting the expansion of U.S. exports. Yet, at the same time, the policies and regulations of various Federal agencies are making it increasingly difficult for ports to gain approval for the construction and maintenance of the navigation channels on which our foreign commerce so heavily depends. Intolerable delays in obtaining the necessary project authorizations have resulted from the extended permitting processes, environmental opposition, and nuisance suits. Moreover, Federal environmental, safety, health, and security requirements have placed additional (and unproductive) financial burden on our ports.

If the government really wants to help, it should begin by cutting back the bewildering maze of regulations and standards and end the bureaucratic inertia that chokes off initiative and discourages progress. At the very least, it should simplify and speed up the permitting process which now threatens to close down our port system. It should resolve the conflicting policies and actions of its own agencies, and cooperate with other interests in working out a policy of common purpose — in this case, a policy of promoting of U.S. coal exports. ■

TOXIC WASTE DANGERS

by John C. Fine

A government survey in 1836 reported on the feasibility of building a canal connecting Lakes Erie and Ontario at a site near Niagara Falls, New York. In May 1892, when William Love arrived in Niagara Falls, he seized on this early engineering survey and began plans for a navigable power canal between branches of the Niagara River. Love commenced building seven miles northeast of Niagara Falls, hoping to connect the Niagara's upper and lower levels. Love was granted a charter by the State of New York, but, almost as soon as construction began, an economic depression in the U.S. scuttled the company's grandiose plans. The economic crisis, coupled with Tesla's development of alternating electrical current — which made it economical to transmit power over long distances — finally dealt a blow to the canal project. Love's company folded.

Mr. Fine, an attorney and counsel for the Senate Committee on Hazardous Waste and Toxic Substances, has written extensively on environmental subjects.

In the 1920s, the Love Canal site, located a short distance from the Niagara River, was converted into a dump by the City of Niagara Falls.

leaving a partially dug trench in the southeast corner of the City of Niagara Falls. The property was sold at public auction in 1910 and for a time thereafter served as a swimming hole for children.

In the 1920s, the site, located only a short distance from the Niagara River, was converted into a dump site for the City of Niagara Falls. From 1920 until 1953 some very deadly poisons were emptied into the canal site. In 1953, the open trench was filled in and the land sold to developers.

In 1978 government officials were forced to respond to a human health crisis of incredible proportions. By that time dozens of homes had been built around the covered over dump site and an elementary school had been built directly over the site where the poisons were buried. Birth defects, miscarriages, liver damage, cancer and a host of health problems were rampant among the 97 families, composed of 230 adults and 134 children, living immediately adjacent to the landfill. The tragedy so affected the lives of the people living around Love Canal that the name will live in infamy as a synonym for uncontrolled and improper disposition of toxic wastes.

Love Canal, although symbolic, represents just one example of disasters of yet unknown proportions that exist around the world. Toxic wastes and hazardous materials have illegally or improperly been deposited directly into oceans, rivers and streams, or contaminate these important water resources indirectly when the poisonous contaminants leach out of landfills or land burial sites. Indirect contamination occurs when dumped, landfilled or buried toxics seep into groundwater or along streams and rivers into the oceans.

To understand the proportions of the problem, we need only examine recent government statistics which show that highly toxic, explosive, flammable, or corrosive byproducts of industry and commerce are presently generated at the rate of some 44 million metric tons per year in the United States. In 1980, industry generated an estimated 56 million metric tons of hazardous waste. Of this, 4.6 million metric tons were produced in New Jersey and 3.5 million metric tons in New York.

Huge quantities of these dangerous industrial wastes have been dumped in the oceans. In the State of New Jersey alone, of 1.2 billion gallons of hazardous waste generated in one year, 600 million gallons were dumped in the Atlantic Ocean. While a great deal of unpermitted, and thus unlawful, ocean dumping continues, all currently permitted dumping of hazardous wastes in the oceans must be stopped by 1981 under the law.

The critical environmental and health peril of this toxic waste dumping was emphasized when high-ranking officials in the United States Environmental Protection Agency recently testified before a New York Special Grand Jury looking into the problem of toxic wastes, that:

"Over 90 percent of the hazardous waste generated in the United States today is handled improperly and may be or is causing detrimental effects to human health and the environment every day."

Thousands of examples exist of direct contamination of water resources. Last year investigators arrested officials and employees of a company which, over a period of years, backed 7000 gallon tank trucks up to the water's edge at Kill Van Kull, the narrow stretch of water separating Staten Island, New York from New Jersey. These persons pumped millions of gallons of poisonous toxic chemical wastes directly into the water. Kill Van Kull flows directly into Raritan Bay and the Atlantic Ocean.

Another example of water resource contamination occurred at Fort Edward, New York. A major industrial company pumped Polychlorinatedbiphenyl (PCB) waste directly into the Hudson River. This contamination, which occurred over a period of years, forced the closure of the river to the taking of fish. While the State of New York knowingly permitted this dumping, the company continued the PCB discharge after the harmful effects and potential human danger became known.

Major problems involving toxic waste contamination occur where manufacturers and transporters, and toxic waste disposal concerns discharge wastes directly into municipal sewer systems. Sewage treatment systems are not designed to handle toxic chemical wastes. The poisonous discharge is often so deadly that it destroys the treatment system itself, killing bacteria that are an important element in the treatment process of septic waste. These nondegradable, deadly chemicals are discharged from the treatment plant directly into the ocean or tributaries running to the sea. The poisons leave the treatment plant in the same condition in which they entered.

Very often toxic wastes are improperly dumped into municipal landfills, either as direct discharges from tank trucks, or in 55-gallon drums trucked onto the landfill. In some cases, where dumpers seek to avoid detection, investigators have found that the toxic chemicals are first dumped into a pool or mixing pit. Household garbage is then dumped in on top of the chemicals and saturated with the toxic liquid waste. The poison-soaked refuse is then loaded back onto garbage trucks and carried to landfill sites and dumped. As a result, these nondegradable contaminants may eventually leach out of the landfill into streams and tributaries or seep down through the soil into aquifers and groundwater. Leaching creates health and environmental time bombs that may explode many years after the original dumping.

The tragedy of improper land burial of toxic wastes is amplified by the fact that very often these landfill sites are built in areas people feel have little residential value. Huge landfills that have received toxic wastes have been sited over swampland, such as the Meadowlands in New Jersey, or in areas of little commercial value around our waterways. The report by the New York Special Grand Jury investigating this problem emphasized this short sighted approach and the danger of contamination from landfills, when it reported that:

A small portion of the 44 million metric tons per year of toxic waste contaminants generated in the US.

The author examines dangerous laboratory chemicals on the border of the Elizabeth River.

"Land disposal sites are often located in areas considered to have little or no value for other uses and without sufficient concern for the type of soil on which they are situated or their proximity to water resources, particularly groundwater. Such improper siting, coupled with limited state enforcement of other standards and requirements, has resulted in groundwater contamination in some heavily populated areas throughout the country.

"Although leachate can be a potent contaminant, the relationship between waste disposal practices and groundwater has generally been ignored by those responsible for waste disposal."

Often, careless acts which occurred decades ago are paying deadly dividends today. One such example occurred in Woodbridge, New Jersey, in an industrial area along Berry's Creek. Berry's Creek flows through swampland directly into the Hackensack River which leads into Newark Bay, eventually flowing into the Atlantic. Before World War One, a company built a mercury manufacturing plant on Berry's Creek. Over the years and through the two World Wars, they dealt with millions of pounds of mercury for the military. Much of the mercury was used in submarines, as flow controlled ballast, for surfacing or descending. Over the years of its operation, tons of mercury were spilled, wasted, thrown out as contaminated or otherwise dumped out by the plant. The mercury found its way into the ground adjacent to Berry's Creek. In early 1979, long after the mercury processing plant was torn down and a large food handling and packing firm was built on the site, town officials discovered that the levels of mercury in the ground were among the highest in the world. Town officials feared a tragedy similar to what happened in Minamata, Japan years before. *(See Water Spectrum, Vol. 10, No. 4, Fall 1978)* The problem was multiplied by the proximity of the contaminant to the creek and some persons expressed fear of its potential migration into the Atlantic.

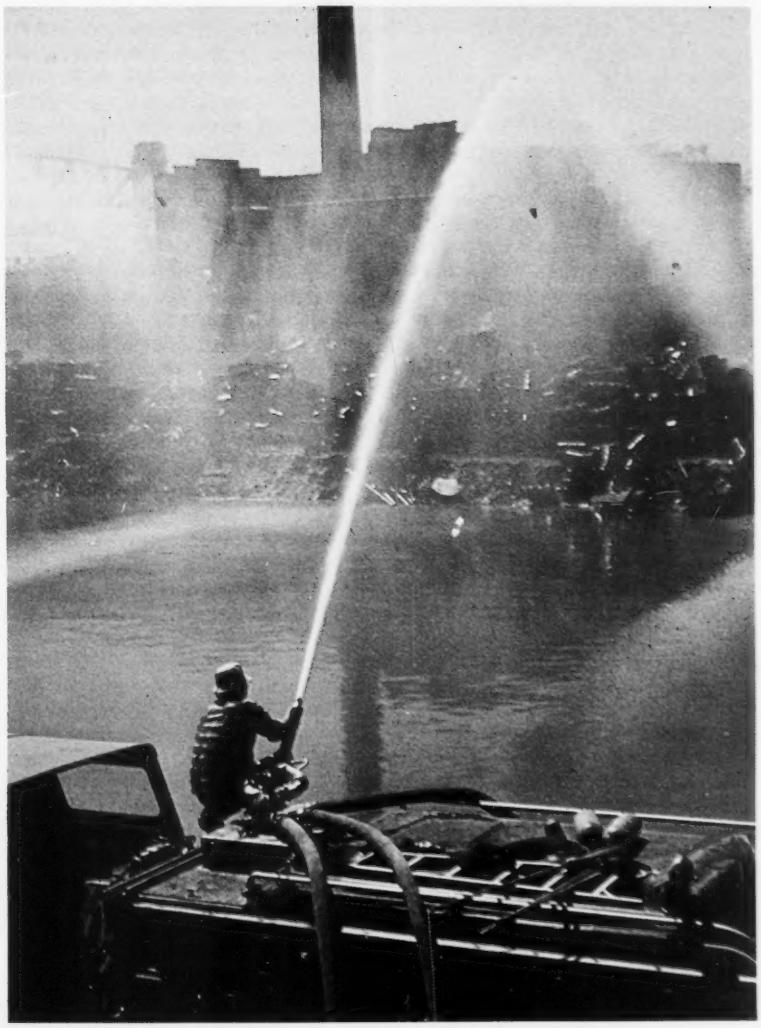
There has as yet been no solution to the problem, ironically complicated by one incident reporting the reluctance of a mercury dealer to want to excavate the contaminated land to recover the valuable metal. *The commercial concern felt there would be so much recoverable mercury, estimated at from 400,000 to 800,000 pounds, that it would depress the market price.*

Responding to the nationwide crisis caused by uncontrolled and improper disposition of toxic wastes, the U.S. Congress passed the Resource Recovery and Conservation Act (RCRA) in October 1976. The Act would not take effect until the Administrator of the Environmental Protection Agency (EPA) promulgated definitive Rules and Regulations. Congress gave the EPA 18 months to issue these rules.

New York's Special Grand Jury, and recent congressional investigations, criticized EPA's failure to promulgate these rules, and thus their failure to give RCRA effect.

There are a number of loopholes in RCRA itself that leave open areas of abuse. Among the areas left unresolved by RCRA is the Act's failure to deal with abandoned toxic waste sites. The ability of a company to evade regulation by acting as a reprocessor or one who states the toxic wastes are for re-use is another area of potential abuse. Another built-in deficiency is that the nationwide manifest system envisioned by RCRA, which would track the toxics from generation to final disposition, will not be effective unless the program is sufficiently staffed to monitor the paperwork and provide sufficient resources to investigate and prosecute offenders.

Site of the April 21, 1980 Chemical Control Plant fire where chemicals were flushed and spilled into the Elizabeth River and Arthur Kill in New Jersey.



Some scientists and engineering experts are raising the issue of the entire concept and safety of landfilling hazardous wastes. Even under present governmental guidelines, landfills, no matter how carefully constructed under today's technology, will not be effective long term, perpetual, means of disposing of hazardous wastes.

This has been made clear by engineering experts whose testimony was reported by New York's Special Grand Jury:

"The objective of a secure landfill is to isolate the hazardous waste from the surrounding environment. Plastic liners on top of clay have been used in New York and elsewhere to line hazardous waste land burial sites. When full, the landfills are usually "capped" with clay and plastic to seal off the chamber. The history of these types of facilities has been all bad. Secure landfills have been "abysmal" as a mechanism for isolating wastes from the environment. In the land burial sites studied by an engineering expert, levels of leachate within the chambers had risen to the brim. At one such facility, a strong odor of "volatile organic chemicals" was being emitted and as many as 300,000 gallons per month of leachate had to be pumped out of a series of closed secure landfills in order to prevent the toxic matter from contaminating the environment."

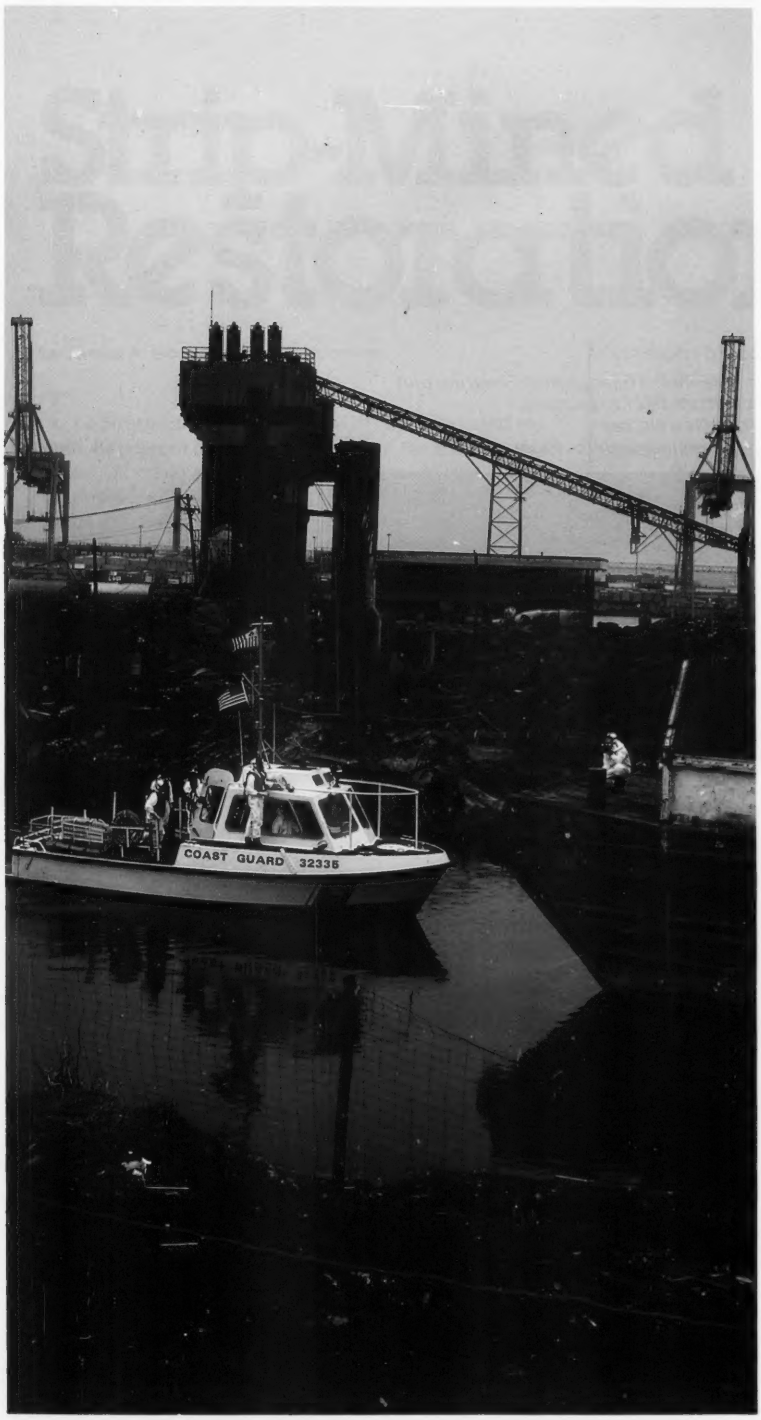
Water samples are taken from Arthur Kill for radiological testing.

One problem with the land burial of industrial wastes is that it is almost impossible to segregate the chemicals to keep them from mixing. PCBs, industrial solvents such as trichloroethylene and trichloroethane and pesticides may, for example, all be placed together in a single land burial facility. Reaction of these chemical wastes coming into contact with each other can radically affect the ability of the protective liners to retard the migration of chemicals out of the site. One example given the N.Y. Grand Jury involved PCBs, which do not pass easily through the clay liners. Once mixed with a solvent such as trichloroethylene, however, they will pass through clay with the same speed as water.

Because of the extreme toxicity and the failure of certain hazardous wastes to degrade, once a parcel of land has been used as a disposal site, the land probably can never be used for any other purpose.

There have been many proposals made by government and industry to try to cope with the waste product at its point of generation. Many toxic wastes can be chemically converted, and in some cases sold commercially. Cutting down on the amount of waste that has to be discarded is one important way of solving the problem. Other proposed solutions involve very high temperature incineration of these dangerous wastes. To date, high temperature incineration is the only acceptable way of disposing of liquid PCBs. In some cases, it may be practical to use PCB laden waste oil and solvents to heat cement kilns, thus incinerating a dangerous waste product and saving energy. The difficulty lies in incineration technology, which often lags behind theoretical solutions. Air quality must be carefully monitored to avoid solving one environmental problem by creating another.

Scientists, government officials, industry and concerned citizens must take the initiative, they must galvanize their efforts to control the generation, transportation, storage and disposition of these hazardous and toxic wastes. No longer can our society tolerate dilatory approaches to the problem like those characterized by the Grand Jury, where:



The US Coast Guard assists with the removal of toxic waste after fire on the Elizabeth River.

"Lax or nonexistent government regulation has left the waste generator largely unhindered in the pursuit of the least costly means of disposing of hazardous waste. This lack of control has resulted in substantial damage to the environment, threats to human health and, ultimately, in massive expenditures of money by the taxpayers to correct the damage done.

"The evidence indicated the response of Federal, state and local governments to the problems posed by hazardous waste has been characterized by ignorance, neglect, laxity and fractionalization of responsibility."

Citizens must insist that Congress press its legislation to control toxic wastes, insuring the implementation of RCRA. Congressional review of the legislation must be continuous to insure that it keeps pace with developments in the field and to be sure that loopholes in the law are plugged. Concerned citizens and environmental groups must continue to petition their legislatures to dedicate resources to this problem, especially in the area of enforcement.

Persons that dump toxic wastes improperly must be brought to justice and dealt with strictly. There have been enough toxic waste horror stories like the one where 5000 gallons of cyanide wastes were dumped into a city sewer system near massive acid holding tanks. Had the two ever mixed, it would have turned a major American city into a gas chamber. The case where a bulldozer operator, putting dirt over a landfill, was killed when he struck a barrel containing explosive hazardous waste, also points up the urgency of toxic waste problems. These issues must be resolved by a commitment to eliminate the conditions that have made these tragic accidents or tragic potentialities possible. The insidious contamination of our land and water resources by toxic wastes will stop when enough people recognize the peril to human and animal health and the environment, and insist on the strict enforcement of our existing laws and, in the case of RCRA, its immediate implementation by the promulgation of long overdue EPA Rules and Regulations.

One of the key elements in this whole process will always be the impetus provided by vigilant and concerned persons working together to insist that the tragedies caused by the improper disposition of toxic wastes be solved. Hopefully, the sad experiences like those at Love Canal will enable us to prevent future harm from toxic wastes both to human and animal health and the environment. ■

Alcohol, Tobacco and Firearms unit disposes of explosives at New Jersey Chemical Control Plant.

Site of the destroyed mercury manufacturing plant on Berry's Creek in Woodbridge, New Jersey.

Strip-Mined River Restoration

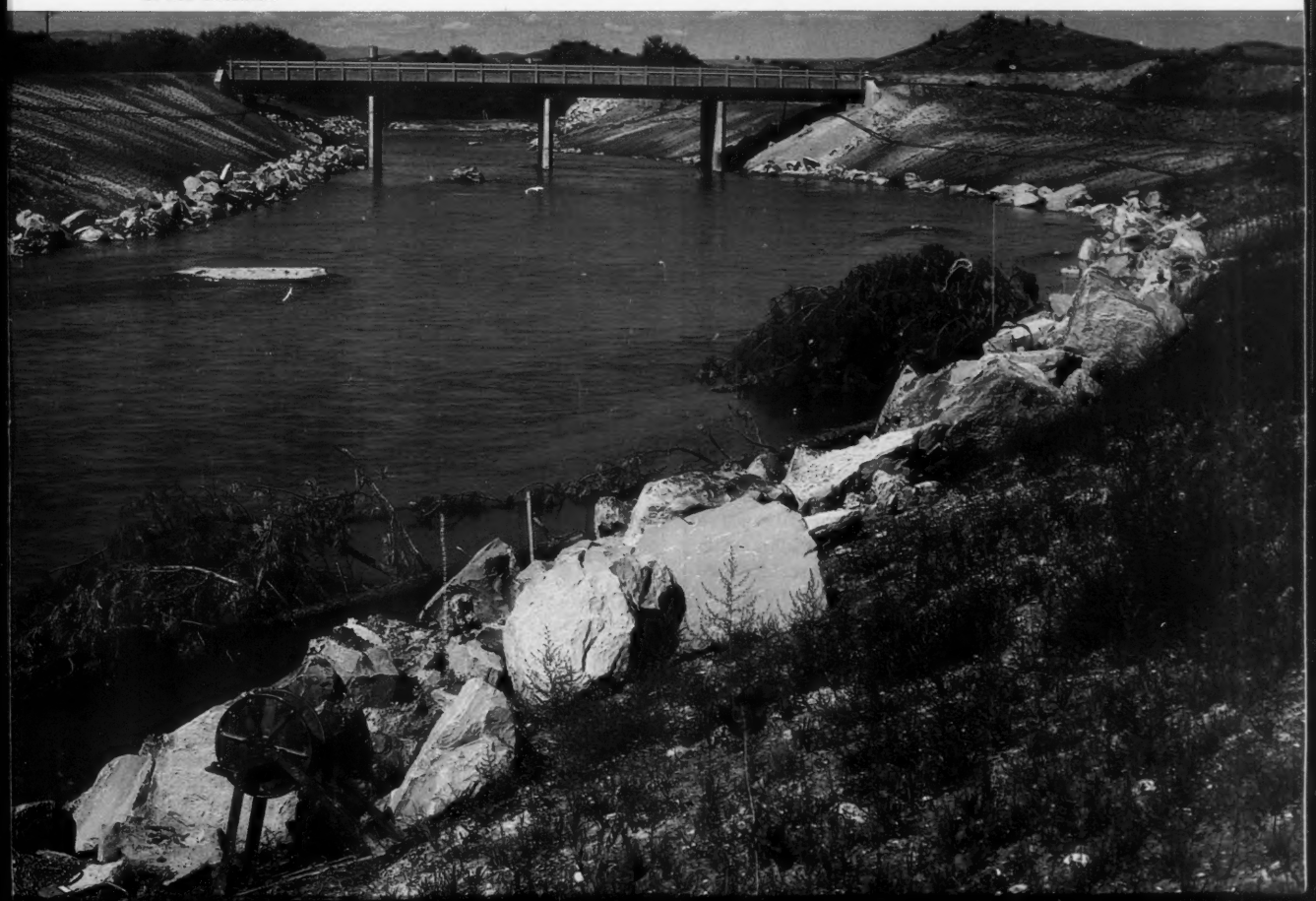
by James A. Gore and Lora S. Johnson

The Northern Great Plains (NGP) are estimated to hold 40 percent of the coal reserves of the United States. The majority of this 2.5 trillion tons is strippable, and the most easily accessible seams are along alluvial valley floors, where the overburden is often eight feet or less. This situation presents a considerable conflict in a semi-arid prairie environment.

Where water is at a premium for urban consumption, ranch irrigation, and support of popular sport fisheries, the impact of surface mining has potential effects on virtually all residents of the area. At the present time, the Office of Surface Mining has imposed a moritorium on mining of alluvial deposits and the Environmental Protection Agency strictly enforces a 100 foot buffer zone along river channels. Nevertheless, increasing demand for cheap domestic energy sources and proposed Federal actions (e.g. the Energy Mobilization Board) may negate these protecticns and cause

Mr. Gore is a research aquatic biologist, and Ms. Johnson a research associate, with the Water Resources Research Institute, University of Wyoming, Laramie 82071.

A reclaimed section of the Tongue River, showing rip-rap, revegetation, pine snags and a large boulder in the middle of the channel.



The Number 1 pit at the Big Horn Mine.

considerable adverse impact to water quality and aquatic biota. It behooves us, as scientists and engineers, to prepare a strategy of river restoration to mitigate these potential losses.

Reclamation problems are varied in the United States. In this article, we propose some methods we have found effective to meet problems in restoration of a typical coal surface mined river channel, specifically in the Fort Union coal formation in northeast Wyoming. This region contains low BTU sub-bituminous and lignite coal. Where eastern anthracite seams are often mined and reclaimed within a year or two, many NGP mines have been in continuous operation for over 40 years. Pyrite formations are rarely associated with NGP coal areas, so problems with acid mine wastes are small. However, the prolonged residence of surface mine operations on ten or more surface acres presents its own unique problems. The greatest problems are fugitive dust, as an air pollutant, and increased sediment in streams and rivers due to barren soil and the slow rate of maturation of revegetated areas.

We were able to examine a complete channel restoration project at Big Horn Mine near Sheridan, Wyoming. In the years before comprehensive surface mine regulations were enacted, a portion of the Tongue River was stripped for underlying coal deposits. The river had been previously re-routed into an unused pit and from there back into the river, downstream of the mine operation (Fig. 1). In 1978, the mine owners, seeing the economic feasibility of re-opening the unused pit, decided to rebuild the original channel and restore the Tongue to its original course. Our experiences and recommendations are based on a two-year study of these hydrologic and biologic restoration practices and their effect after the channel opening in August 1978.

It seems in the restoration effort that only a short length of river (one-half mile or less) would likely be diverted from mining at any given time. Thus, meander pattern would not seem, initially, to be a critical design

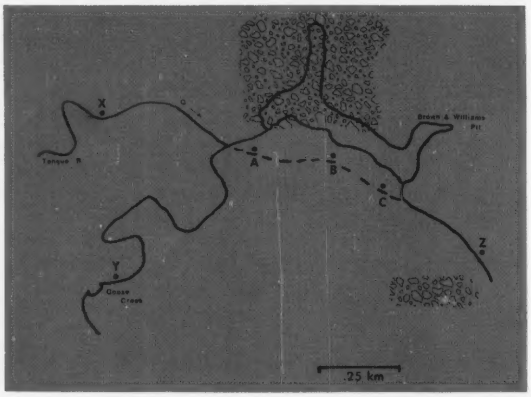


Fig. 1 — Map of reclaimed section of mine at the reclaimed site. Dotted line is the path of the newly restored channel. Stipple area shows active mine operation.

problem. A straight-run channel is probably not advisable, as shear stresses along embankments and along the bottoms of channelized streams have been shown to cause increased suspended load and to obliterate benthic habitat. The increased load causes fouling of invertebrate and fish gills. We have found, on a site specific basis, that a pre-designed meander pattern reduces bank sloughing and concurrent increased suspended sediment. This design is rather simply based on pattern in comparable length stretches upstream and downstream of the restoration area so that the newly directed flow from the upstream reach has its energy dissipated to avoid serious cutting of newly formed embankments. This design is a logical extension of the considerable research accomplished by geohydrologists in the NGP coal areas who have found the restoration of meander patterns of NGP streams, on a gross scale, leads to a reliable degree of hydrologic stability.

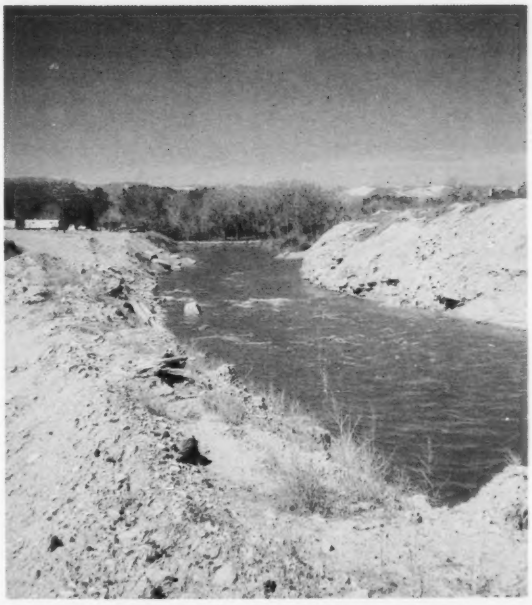
Composition of the substrate is critical to establishment of good biotic communities and in maintaining hydraulic stability. Previous research has shown that aquatic insects, the primary fish food source, show a high specificity for certain substrate particles and profiles. In the Tongue River, our previous work revealed the highest diversity of aquatic insects to occur in shallow, high velocity riffles, with a substrate of small and medium cobble. Because small gravels are beneficial to some invertebrates and are particularly necessary for successful spawning of some fish species, we suggest, as in our research channel, that an initial layer of gravel be covered by a mixed layer of gravel, small, and medium cobble to a depth of at least two feet, as was designed in the prototype channel. The bed cemented rapidly and is still in place. Although no stream is uniform in substrate distribution, we have found this substrate mixture in the restored channel to be colonized by benthic invertebrates closely approximates the density and diversity levels found in unstressed areas.

Although not strictly related to our restoration project, revegetation is necessary to control erosion. Banks along the channel were successfully hydromulched with grasses and legumes. An attempt to establish native woody species by hand planting of seedlings was not as successful, as only a small percentage of the seedlings survived the first winter after planting. However, a high spring runoff aided in the natural revegetation of riparian and rip-rap areas by cottonwood seedlings.

We found that a rip-rap of large boulders (up to four feet in diameter) effectively blocked the large scale bank sloughing often encountered in some stream channelization projects.

Cover is an essential component of habitat for many fish species. In general, cover increases habitat complexity which can lead to a richer species complex. Specifically, cover provides hiding places for both adults and try to escape predation. Its slowing effect on water velocity provides a metabolic resting place and, under some circumstances, cover provides increased

Typical stretch of the Tongue River in the Montana Northern Great Plains region.



Diversion channel into Brown & Williams Pit prior to reclamation.

substrate for food items and for egg attachment. Typical forms of stream cover are undercut or overhanging banks, deep water (pools), log jams, "snags" caused by accumulation of floating debris in the branch complex of fallen trees, large boulders or boulder piles, and, in winter, ice cover.

In stream restoration, cover must be provided to induce fish colonization. If it is likely that spawning will occur in this area, artificial structures must be made or made to occur naturally. For example, large boulders, placed in the river channel of the Tongue River, freeze-fractured over the winter months. The subsequent process of eddying behind large boulders

and displacement of fractured pieces caused formation of extensive gravel and rubble bars the following spring. We have observed fish spawning on these bars.

Aside from large boulders in the thalweg (deepest part of the channel) of the stream, other cover structures must be placed. Pooling along the banks aids resting or rearing needs of fish and reduces shear stresses on newly constructed embankments. Rock wings and/or snags are favored pooling devices. Deciduous trees, having complex branch networks, would be optimum for snag construction. In the NGP region, deciduous trees grow almost exclusively in the flood plain, however, within the protected buffer zone, thus other measures have to be found.

Brown & Williams Pit, unused, and filled to a depth of 45 feet with diverted Tongue River water.

Initial reclamation construction showing embankments. There is a bridge in place over river since pits are operating on both sides of river channel.

At the Big Horn Mine, pine trees, removed from future surface mine areas, were anchored by cable and stake into the rip-rap areas. Sets of four or five trees were placed at an approximate angle of 30° from the downstream shore line. Although branch complexity is not as great, the pines retained most needles for up to a year. The needles, themselves, provided considerable complexity. In the initial design, pooling behind these snags was anticipated, and did occur.

Although the channel was originally planned to be of uniform depth and width, the closing and re-diking of the outlet diversion from the unused pit caused a large pool of increased depth to form in the lower channel. This had some unplanned benefits to reclamation. Slow water and deep pools provided cool waters for fish in hot, low-water summer months and provided a settling pond for increased sediment load. No downstream sediment starvation was noted.

Aquatic macroinvertebrates colonize new habitat by a number of methods. The primary method (up to 95 percent of initial colonization) is by drift. This event naturally occurs in unstressed invertebrate communities on a daily basis. Either through interspecific displacement or mechancial dislodging, aquatic insects resettle in appropriate habitat further downstream.

In stream restoration, the drift mechanism is most important in establishing new aquatic invertebrate communities. Thus, maintenance of an undisturbed upstream community is necessary for rapid recovery in the new channel. Establishment of a "stable" biotic community can occur rapidly. In our study, areas within 200 yards of an undisturbed area reached maximum densities in about 75 days and stable diversities in 250 days. Because aquatic insects have a variable drift rate, areas further downstream show

Tongue River stonefly on invertebrate sampling bag. The presence of this species in reclaimed stretches indicates that an equilibrium community has most likely been established.

A tagged adult rock bass, the indicator species for the recovery of the fishery community.

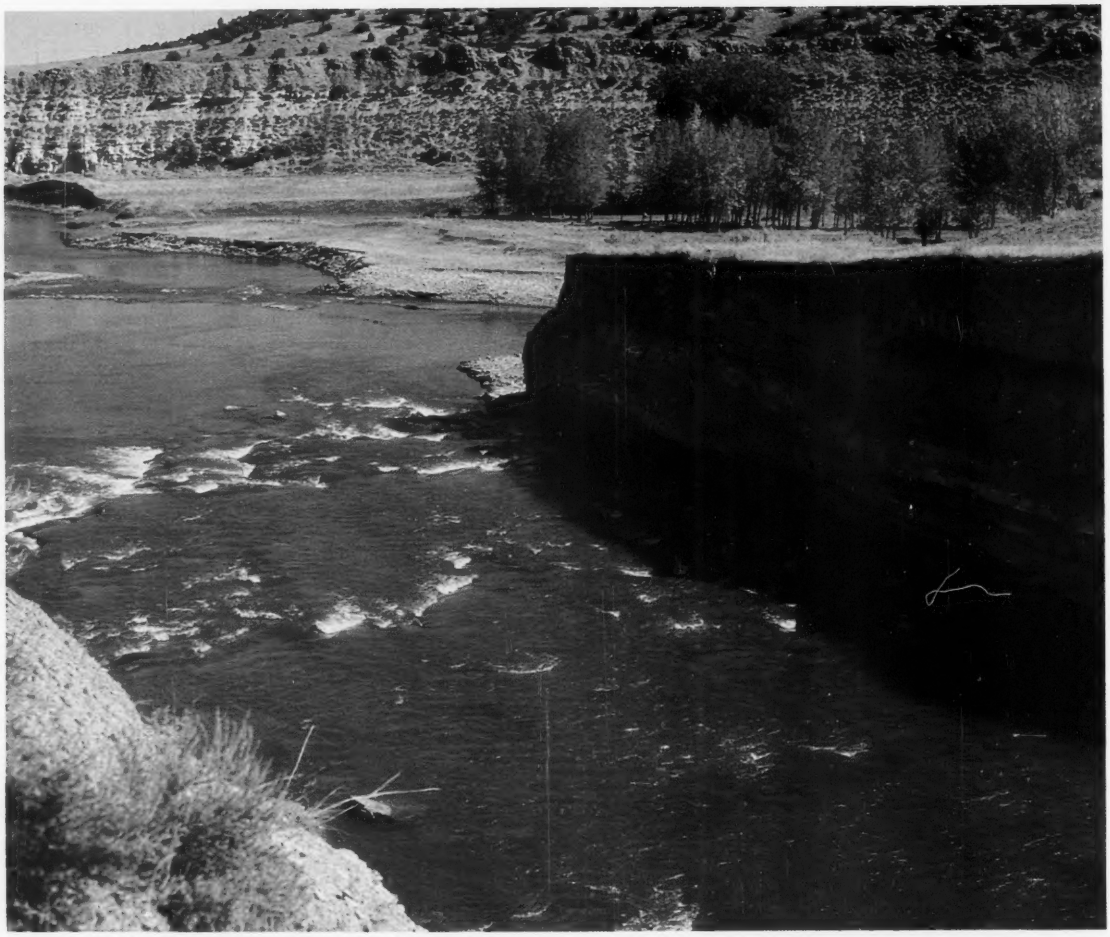
The common snapping turtle was the first verified permanent resident vertebrate.

recovery at sequentially later dates (Fig. 2). Mayflies, which occur commonly in drift, can occupy all sites within a short period of time. However, low frequency drifters, like attached insects and predators such as dragonfly and stonefly nymphs, may take as long as 400 days to reach the same areas which mayfly nymphs reached in 21 days or less. This delay to achieve a stable community implies a maximum distance over which recovery in a reasonable amount of time can occur.

Our predictive equations estimate that distances of less than 1.5 miles in total length can be mined and reclaimed for adequate initial recovery in two years. Of course, these predictions are based solely on the data from aquatic invertebrates. As can be seen in the following discussion, recovery can be further delayed by unsuccessful fishery recovery.

Drift of aquatic insects varies from season to season in a given year. This imposes constraints on the optimum time to begin restoration work and diversion of the river back into the restored channel. Drift, and subsequent colonization, is highest during early spring and late summer. Thus, the timing of the opening of the channel to coincide with periods of high drift insure the most rapid establishment of a stable benthic community. Fortunately, the late spring and summer months, after the ground has thawed, is the most ideal period for channel restoration in the NGP. Timing for the late summer drift increase can be easily arranged. Unfortunately, these same months are periods of easiest coal accessibility and are demand months for high coal

Area immediately upstream of reclaimed area served as source of invertebrate colonizers. Power house in the background is the last remnant of the town of Acme, Wyoming, bought up by the coal concerns and removed to facilitate future surface mining.



Stretch of the Tongue River in Fort Union formation near Decker Mine, Montana. Note that cut has exposed several layers of coal, with an overburden of less than five feet.

production for winter reserves. Mine personnel needed to reconstruct these river channels may be difficult to recruit away from high priority mine production work.

Some upstream migration by aquatic invertebrates has been reported. Adult egg-laying flights, usually in an upstream direction, can also contribute to stream recovery. However, these are rather small (5 percent or less) contributions. But, if an ecotonal (transitional) area is being surface mined, the downstream undisturbed area must also be maintained to insure a source population of species not existing in unstressed upstream source areas.

Colonization by fish can occur more rapidly than that of invertebrates. Fish do not have to rely on passive dispersal (drift). Active invasion can come from both upstream and downstream at approximately equal rates. Seasonal changes in species composition of colonizers related to spawning, establishment of territories, and water temperature optima are to be expected.

The majority of species available as potential colonizers were collected at least once in the restored portion of the Tongue River. Fish biomass however, was at a much reduced level when compared to undisturbed sites in the area. The snags were, by far, the preferred habitat location. In general, bottom feeding forage fish, such as suckers, chubs, and dace comprised the initial colonizers. Successful spawning by suckers and minnows had taken place in the snags by the following spring. Inundated rip-rap, in the lower pool, was favored by smallmouth bass. As mentioned previously, the lower pool was a preferred resting and spawning area for northern redhorse suckers in hot summer months.

The successful establishment of a restored channel fish community is difficult to detect due to the high mobility of fish species. It would be expected that piscivorous fish, those that, in the main, feed on other fish, and territorial fish would be the final invaders. We suggest that, if such a species is present as a potential colonizer, a highly territorial fish species be used as an

indicator of satisfactory new channel habitat conditions. In the Tongue River, rock bass were found to maintain a territory of 200 feet radius or less. A few adults were captured and tagged after channel opening. No marked adults were recovered in subsequent samples. However, successful recruitment of young-of-the-year rock bass was accomplished the following summer. Some tagged fingerlings were recovered and appeared to have established territories in the restored channel. Although overall fish densities were still low, we determined that, with the occurrence of territorial rock bass, a stable community had been established in the habitat available.

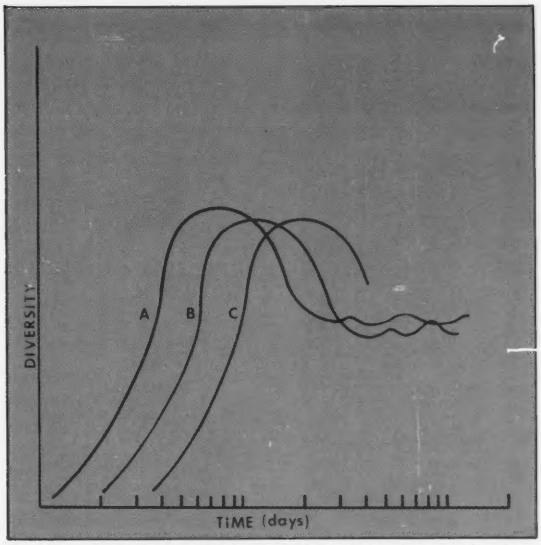
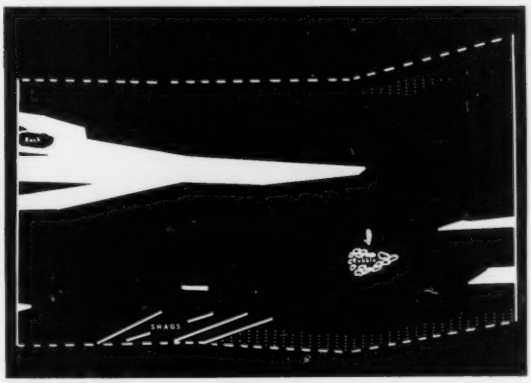


Fig. 2 — Graph of aquatic macroinvertebrate colonization and equilibration over time at restored river channel. A, B and C are sequentially further downstream sample sites.

The severe winters in the NGP region slow effective revegetation and reclamation.

Low fish densities were attributable, in some respects, to localized changes in channel hydraulics. Monthly measurement and observation of typical channel profiles (See example in Fig. 3) showed that the substrate of medium and small cobbles became rapidly cemented. However, predictions of localized meander patterns (i.e. shifts of 1-2 feet) are still relatively inexact and some changes in stream energy vectors from those predicted should be expected.

These changes are accommodated by rearrangement of the loosely compacted soils in the shoreline rip-rap zone. In this way, one set of snags was left "high and dry" by a shift of the thalweg of the stream a few feet from that predicted. In essence, one-third of planned available fish habitat was removed from the new channel, and water surface elevations were basically unchanged. The importance of snags as habitat structures was born out in computer projections of available habitat. Composite maps of velocity and depth contours (See Fig. 4) have been used to predict availability of optimum habitat for various fish species, based on that species' instream flow requirements. With a set of contour maps generated from a year of measurements at various discharges, it is possible to add structures to the computer simulation and to derive new predicted flow patterns. Combined with known flow requirements of important resident fish species and aquatic invertebrates, a computer simulation of the restored channel could aid mine engineers in initial construction of the channel for best productivity of fish and invertebrate species. In this manner, for example, we have recommended that the number of snag structures be increased from three to six per quarter mile of reclaimed stream. These structures should be placed on alternate banks at intervals of 75 yards. Gravel bars, large boulders, and pools can also be designed and placed through computer projections. It is possible that planned construction of depressions which form pool areas behind large boulders may induce a more rapid establishment of a high diversity of fish fauna. Only

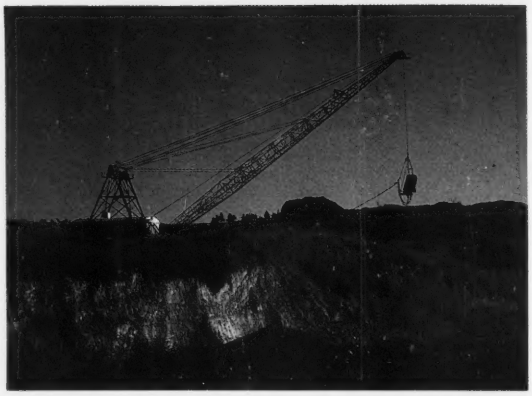


Composite velocity and depth maps used to simulate available habitat. White areas are optimum rearing or maintenance habitat for the stonecat, Noturus flavus. *Stippled areas are optimal for spawning for the sauger,* Stizostedion canadense.

after these small pools were naturally formed (up to two years subsequent to channel opening) did more uncommon species, like whitefish and trout, appear in the new channel.

In a strip-mine altered NGP river, an increase in suspended sediment is of major concern. Alternations in water quality and potential for mechnical damage can be a costly problem for downstream ranchers and farmers. The formation of the large pool at the lower end of the reclaimed channel provided us with an important bit of research information. Not only did the pool provide increased cover for fish (by deep water and inundation of rip-rap), it also provided a settling pond effect on suspended sediment. During the entire research period, suspended sediment concentrations remained up to twice as high as comparable measurements in undisturbed areas. Bed load was not measured, but it is felt that little effect would be observable. This increased load level was slowly declining with maturation of vegetation on the embankments. Because of the location of the accidental pool, and the fact that concentrations of suspended sediment returned to normal levels at the sample station 100 yards downstream of the restored channel, we suggest construction of a deep pool at the downstream end of the reclaimed reach to aid in control of increased suspended load. As revegetated areas mature, this pool can be further managed as a high productivity fishery with upstream runs and riffles as primary feeding areas.

The Northern Great Plains will continue to be subject to surface mining impacts for many years. Based on present American consumption rates, economists predict that the NGP coal region could support all



Dragline operation at Number 2 pit. In the foreground is part of the 100 foot buffer strip along the reclaimed river section.

American energy needs for 150 to 250 years. NGP state senators and representatives see a tough fight ahead, yet the need for effective reclamation legislation and research is of high priority. Our preliminary research indicates that, with careful planning and consultation between biologists, hydrologists, and mine engineers, an effective restoration program can be implemented. Newly developed computer simulations can add to this planning strategy. This does not imply that reclamation will be simple nor inexpensive. In a semi-arid environment, like the plains of Wyoming, Montana, and North Dakota, estimates of 10 to 20 years for full restoration are not unreasonable. The ultimate benefits of river integrity to consumers in the region as well as to tourists are well worth the efforts. ■

Aquatic biologists keep constant watch on the biota in the reclaimed river reaches.

SALMON:

A Second Look

by John Ferguson

Editor's Note: The subject of juvenile transportation of fish, dubbed "Operation Fish Run", was first addressed in the Fall 1977 issue of *Water Spectrum*. The reader is referred to this article for a discussion of the program's historical development and a general overview. The purpose of this article is to update the subject, present the latest technical information, and cast a speculative eye toward the future of juvenile transportation and passage on the Snake and Columbia Rivers.

Mr. Ferguson is a fishery biologist with the Walla Walla District, U.S. Army Corps of Engineers.

Life within the Pacific Northwest can be defined by its most important element — water. A multitude of natural resources and commercial interests are dependent upon the region's rivers and oceans. There are rivers, dozens in fact, penetrating a large variety of western terrain and climate. A review of the geography of the land reveals two giants which stand out, the Snake and Columbia Rivers. Together, these form the economic and environmental foundations of the land. Although their physical structure varies greatly, these two rivers share a common denominator — anadromous fish. These species, which spawn in freshwater and grow to maturity in salt water, are an integral part of the Pacific Northwest.

For centuries the salmon has held a high religious significance for the Indian nations as well as being an important food source. For the white man they are important as a food item and for the millions of dollars they annually bring to our economy. They capture our imagination, luring us with their romantic life cycle of travel, unyielding struggle, and uncompromising death.

Pacific salmon of the genus *Oncorhynchus* and steelhead trout *(Salmo gairdneri)* have a unique life cycle. In the ocean they grow fat from abundant food sources. Here, too, they feel the first twinge of sexual maturity which triggers with unerring accuracy their return to the natal stream. Two to five years in the ocean provides the strong bodies needed to carry them as far as 1000 miles upriver.

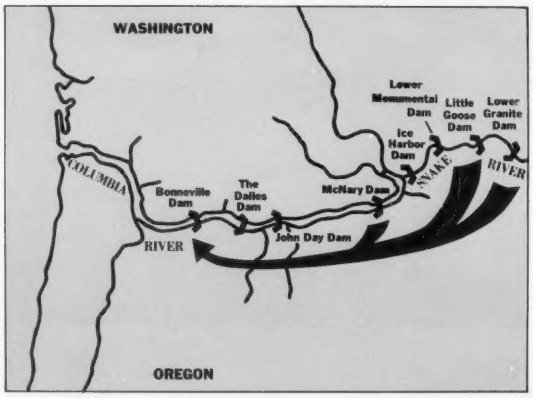
Prior to the spring freshet, or runoff, they begin to smolt (a process by which their body changes physiologically in preparation for the completely different environment of salt water). This smolting process triggers the urge to migrate downstream. When temperature and flow unite at appropriate levels, juveniles leave their birth streams and begin the long migration to the sea, traveling the region's major arteries — the Snake and Columbia Rivers.

The Columbia River system, one of the most productive salmon rivers in the world, still supports a $200 million annual salmon and steelhead trout fishing industry. Declines in the number of salmon have been occurring since the late 1880s, and the utilization of Columbia River stocks has changed greatly over the years as the catch shifted back and forth between Indian and non-Indian fishermen. The decline has been caused by a multitude of factors — overfishing, agricultural pollution, industrial pollution, logging, irrigation withdrawal, blockage from the spawning grounds, and mainstem hydroelectric development.

The Corps of Engineers' role in the damming of the Columbia River began in 1938 with the completion of Bonneville Lock and Dam at River Mile 145. Since then the Corps has constructed McNary (1953), The Dalles (1957), and John Day (1967) on the Lower Columbia; and Ice Harbor (1961), Lower Monumental (1969), Little Goose (1970), and Lower Granite (1975) on the Lower Snake.

Extensive hydroelectric development in the lower reaches of these rivers presents a unique problem for ocean-bound salmon and steelhead trout. The once constant fall of the river has been changed to a series of slow-flowing reservoirs. As a result, juveniles now face a series of obstacles as they travel to the sea. With additional hydroelectric development, negative effects on the out-migration became all too apparent. Research studies identified the causes of mortality as:

- Passage of juveniles through generating turbines and over the spillways.



Juvenile fish transportation route from Lower Granite and Little Goose on the Snake River, and McNary on the Columbia River, to below Bonneville dam.

■ Delays in the timing of the migration through the reservoirs.

■ Gas bubble disease caused by the supersaturation of river water with atmospheric gas (air).

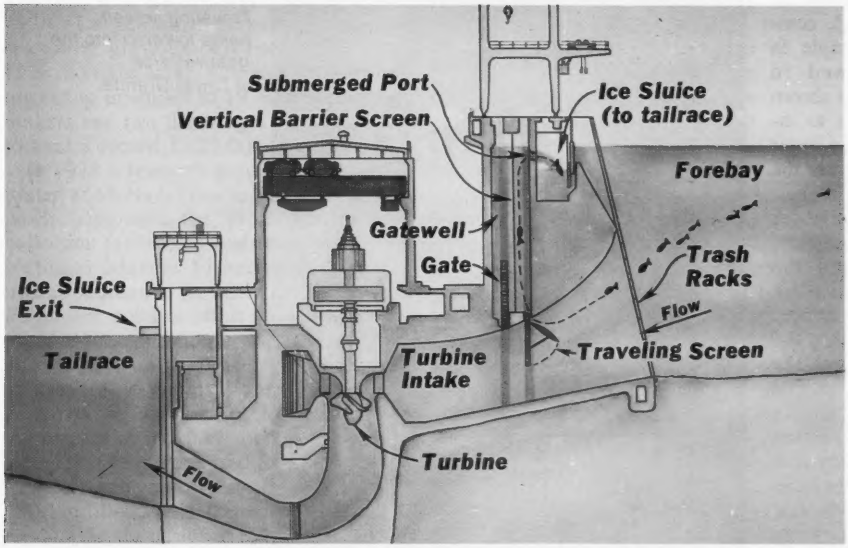
Mortality through the generating units has been shown to average 15 percent at each dam. This is a combination of pressure drop along hydraulic shear planes formed at the trailing edge of the Turbine blades, and direct contact with the blades themselves. When the combined turbine mortalities are calculated for the eight Corps projects, the effects are substantial. Low run-off years result in a higher percentage of available flows going through the powerhouse, and impacts to the migrating juveniles are proportionately higher. Mortality over the spillways is much lower, averaging an estimated 1 to 2 percent.

The additional time it now takes for the smolts to travel through the slowflowing reservoirs causes delays in their out-migration. It has been estimated by the National Marine Fisheries Service (NMFS) that prior to dams being in place, smolts took 22 days to get from the Salmon River to the Columbia River below Bonneville Dam. NMFS estimates that with the current impoundments the journey takes 54 days.

Under low-flow years, such as the drought of 1977, this delay can also result in a significant portion of the juvenile population becoming residual, i.e., losing the migratory urge, staying in freshwater flows, and not attempting to reach the sea. This delay also allows for increased predation, adversely affecting the juvenile population.

Finally, when water is released over the spillways it plunges deep into the stilling basin below the dam. This deep plunge causes entrapped air to dissolve into the water at levels higher than saturation. These supersaturated levels cause nitrogen gas, the major component of air, to enter the juvenile fish, creating a condition similar to the "bends." In severe cases an embolism will eventually kill the animal. Structural modifications to many of the Corps spillways have eliminated much of this problem.

To alleviate these mortality, delay, and supersaturation problems, a logical solution was to collect the juveniles at the upper dams and transport them to a release site below Bonneville. Operation Fish Run accomplishes this collection and transportation, and reduces the juvenile migration time to pre-dam levels.



Cross-sectional view of a mainstem hydroelectric dam.

In carrying out the operation, young salmon and steelhead migrating to the sea are collected at Lower Granite, Little Goose and McNary Dams. Specially-designed tankers and barges are used to transport the fish safely around the remaining dams to release sites below Bonneville Dam. Once there, the juveniles can freely move to the estuary and ocean without further delay.

The collection systems utilized in Operation Fish Run, although complex in reality, are quite simple in theory. They were designed in response to research which has shown that juvenile salmonids prefer to inhabit the top 12-15 feet of the water column. This causes them to enter the upper portion of the turbine's intake.

A traveling screen, which serves as the heart of the collection system, deflects the juveniles up into the gatewell slots. From here the fish are attracted by lights to exit via orifices into the collection channel within the dam. This channel transports the juveniles around the dam to holding facilities below. The young fish are then separated from the collection water and placed into hatchery-like raceways. From the raceways they can easily be loaded into trucks or barges, or guided into a building for marking, examination, and species composition calculations.

Operation Fish Run was initiated in 1971 and maintained in a research mode through 1976. The severe regional drought of 1977 forced state and Federal fisheries management agencies to take immediate action. Juvenile transportation was reviewed, deemed successful, and the decision was made to continue on a larger scale.

In 1977, with the addition of two fish transportation barges to the existing fleet of five 3500-gallon truck-tanker units, the scope of Operation Fish Run changed dramatically. This added transportation capacity allowed the number of transported juveniles to more than double.

The 1977 operation indicated that barging the juveniles was by far the most economical method available. The barges have the advantage of circulating a continuous supply of river water through the holding tanks, thereby allowing the juveniles to "imprint" on the river water during the entire two-day trip downriver. This imprinting process enables the returning adults to detect or "smell" their natal stream accurately. Juveniles transported directly from the hatcheries to the estuary often lack this "imprint." They display confused migratory patterns, straying into side rivers along the migration route. They are often delayed from, and sometimes fail, to return to the hatcheries.

Traveling screen being lowered into the gatewell slot at Lower Granite.

The number of juveniles collected and transported during the 1978 to 1980 period increased drastically (Figure 1). This increase in the number transported is a result of good years of both hatchery and wild-stock production, and increased collection capacities. A chronological presentation of the period from 1978 to 1980 is presented below.

The Pacific Northwest experienced a year of near normal water runoff in 1978. Large adult returns to the spawning grounds (escapement) in 1976 brought large numbers of outmigrating juveniles in 1978. The five tankers and two fish barges were used to haul a record 5,422,000 smolts.

In 1978 a research program was initiated at McNary Dam to evaluate the newly completed fish protection and collection facilities. Conducted by the National Marine Fisheries Service under contract to the Corps of Engineers, a major effort was made to observe the condition of the juveniles and to start up the fingerling bypass and separator systems. Tests were also begun on the initial use of three traveling screens at McNary. Juveniles collected that year were used for research purposes and returned to the river.

In addition, field testing of a fish-guiding device designed to be as effective as the traveling screen, but much less costly, was begun in 1978 at McNary. This was a bar-scoop screen designed to guide juveniles into the gatewell slots without the expensive and troublesome moveable aspects of the traveling screen. Three bar-scoops were installed and tested. Results indicate that although guiding efficiency was comparable to the traveling screen for most size classes of juveniles encountered, the cost of maintaining an adequate backflushing system (debris removal) was prohibitive. Based on these studies all screens purchased since then have been the traveling type.

In 1979 water run-off was again near average. That year all 12 turbine intakes at Little Goose and Lower Granite were screened for the first time. A total of 36 traveling screens

Figure 1

ANNUAL NUMBERS TRANSPORTED AND COST

YEAR	NUMBER OF SMOLTS HAULED[1]	COST[2]
1971	263,000	$ 544,000
1972	587,000	578,000
1973	423,000	365,000
1974	0	285,000
1975	963,000	264,000
1976	1,186,000	794,000
1977	5,400,000	784,000
1978	5,422,000	1,165,000
1979	5,308,000	1,425,000
1980	10,391,000	1,304,000

[1]Includes transports from hatcheries
[2]Does not include cost of trucks, trailers, barges, fish screens, and other project fish facilities

Fingerling collection flume at McNary, transporting juveniles from the gatewells to the collection facilities.

were now deflecting juveniles into the gatewell slots on the Lower Snake River.

At McNary, juveniles were mass transported for the first time in 1979. Estimates indicated that McNary's fingerling facilities could collect 20 percent of the fish migrating past the dam. With this collection efficiency a total of 1,247,000 juveniles were transported from McNary.

Snake River transportation totals were 2,367,000 from Lower Granite and 1,454,000 from Little Goose in 1979. These collection and transport totals, combined with those fish hauled directly from various hatcheries, yielded a total transported of 5,308,-000. Of the total, 62 percent were transported in the two Operation Fish Run barges.

The Little Goose fingerling bypass and collection system was being reconstructed that year. Juveniles had to be dipnetted from the gatewell slots into portable cranes and specially-designed nets. The fish were then emptied into the tanker trucks and transported either downstream or into a transportation barge moored in the navigation lock. The bypass being constructed was designed to alleviate stress and mortality problems associated with the original Little Goose system and to prepare for the handling of larger numbers of fish.

A near normal runoff combined with excellent transport conditions in 1980 produced another record year. Unseasonably cool weather caused the initiation of the transport season to be delayed until mid-April. When water temperatures and flows finally began to rise, tremendous numbers of juveniles were anxious to start their downstream migration.

Lower Granite's daily collection totals exceeded all expectations. At one point 254,000 juveniles were collected in a 24-hour period. The highest daily count ever recorded previously was 165,000 in 1978. A total of 3,835,000 juveniles was transported from Lower Granite in 1980.

The high collection totals at Lower Granite carried through to Little Goose. The newly completed bypass and collection system was operated and fine tuned. A permanent fish barge dock was used for the first time. That year 2,283,000 juveniles were collected and transported from the Little Goose facility.

Fish transportation truck.

The 1980 season at McNary reflects the high upstream collection totals. A record 1,750,000 smolts were transported.

In 1980, a total of 7,861,000 juveniles were transported from the three collection systems. Of this roughly 60 percent were transported by the two fish barges. When those fish which were transported directly from the various hatcheries are added to these figures, a final total of 10,391,000 juveniles were transported in 1980.

Of the three collection sites, McNary has the longest collection season due to its location on the Columbia River. During the spring out-migration Snake River chinook salmon and steelhead trout and Columbia River chinook, coho, and sockeye salmon and steelhead trout are collected. Columbia River fall chinook dominate McNary's summer out-migration which continues through August.

One event of major importance, unique to the 1980 transportation program, was the Mt. St. Helen's eruption. Fortunately, the ash fallout did not cause significant problems to the juveniles being held, or the transporting equipment, at the three collection sites. Poor visibility did cause one of the barges to pull off the river for a few hours during the afternoon of the first eruption on 18 May.

National Marine Fisheries Service personnel sampling the estuary near Longview, WA, reported that immediately after the flooding of the Cowlitz River, the suspended sediment levels in the Columbia River below the Cowlitz were extremely high. Experts felt that juvenile fish were adversely affected by these high sediment levels. The silt, being gritty and abrasive, was causing damage to gill tissue. Juveniles released anywhere upstream from the mouth of the Cowlitz River were affected.

Corps equipment and drivers were readied for the inevitable shift to an all trucking mode to the mouth of the Columbia River. Fortunately, the sediment levels in the Columbia River quickly returned to acceptable levels once the initial flooding subsided. Barging operations continued on schedule.

The Cowlitz River, however, continued to be devastated. An emergency evacuation of the State of Washington's coho salmon hatchery on the Cowlitz was undertaken. Since the barges could handle the moderate numbers being collected this late in the season, all available Corps trucks and drivers, along with equipment and manpower from National Marine Fisheries Service and Bonneville Power Administration, were sent to the hatchery. Mt. St. Helen's erupted again cutting this rescue effort short. The trucks came home and Operation Fish Run returned to a normal schedule of transport operations.

In 1977, dramatic changes were made in the scope of Operation Fish Run with the addition of the transportation barges and various mechanical systems. The period of 1978 through 1980 was relatively identical mechanically although the numbers collected continued to increase drastically.

We expect 1981 to be another pivotal year. A third fish transportation barge is being designed and constructed. A total of 52 additional traveling screens have been ordered to fully screen all 26 generating turbine units at Lower Granite, Little Goose and McNary Dams. Additional raceways are being constructed to meet the expected demand for holding capacity at Lower Granite and McNary. A third tug will be contracted to push the additional barge. The subject of a fourth barge has been discussed and the need for this additional transportation capability will be determined in the near future.

Fish transportation barge on the lower Columbia River.

Under the authority of the Lower Snake River Fish and Wildlife Compensation Plan, the Corps is responsible for constructing a series of hatcheries in the Snake River basin. Juveniles have already been released from the McCall Hatchery, McCall, Idaho. It is estimated that when these hatcheries are rearing and releasing juveniles at full capacity, a total of 1,929,300 pounds of juvenile salmonids, totaling 26,930,000 individuals, will be available to migrate. Presently we have the ability to produce, from hatchery sources, 10,000,000 smolts in the Snake River and 14,000,000 smolts above McNary. These, combined with the out-migration from wild stocks, indicate that an unprecedented number of juveniles will be available for transport from the Snake and Columbia Rivers. It is not unreasonable to anticipate that in the near future Operation Fish Run will transport 15 to 20 million juveniles annually.

Although the number of smolts transported within the past few years has been impressive, and the number available for transport in the future looks extremely bright, the bottom line as to the success of Operation Fish Run is the number of adults returning to spawn. Research conducted by the MNFS has shown that transport benefit ratios vary dramatically depending upon the year. Low-flow years such as 1973 and 1977 are extremely hard on migrating juveniles. Under these conditions transportation is most beneficial. High-flow years simulate pre-impoundment conditions; control groups marked and released into the river survive under high flows at levels that approach those of the groups marked and transported. The successful returns of various marked groups indicate how beneficial specific transport conditions and methods are (Figure 2).

The task of determining quantitatively the success of Operation Fish Run is at times a difficult one. We might assume that when juveniles are released into the Lower Columbia they are subjected to equal survival conditions throughout the transport year (April through August), and over the time span of Operation Fish Run (1971 to present). This, however, is not the case. The success of excellent transport years can be masked by poor estuary conditions, poor ocean survival, overfishing by commercial interests, and a multitude of other factors that have not been quantified. Therefore, we must rely on adult returns as indicators of the success of the program.

The 1978-1980 return of adults to upriver tributaries was influenced by the drought year in 1977 when the out-migration was most probably destroyed except for the efforts of Operation Fish Run. Adult returns for this period have been less than expected for some species. Steelhead above Ice Harbor appear to be doing well. Chinook salmon (springs, summers and falls) have recently shown depressed runs in the Snake River drainage.

At McNary indications are that transportation benefits all species (steelhead, chinook, coho, and sockeye). These research results, while encouraging, are viewed as preliminary. Marked adults are just beginning to return from transport and control groups released in 1978 and 1979.

Figure 2

TRANSPORT BENEFIT RATIOS

YEAR	LOWER GRANITE		LITTLE GOOSE		McNARY				
	SCS	SHT	SCS	SHT	SCS	FCS	SHT	CO	SO
1971	—	—	1.6:1	1.7:1	—	—	—	—	—
1972	—	—	1.1:1	3.25:1	—	—	—	—	—
1973	—	—	15.4:1	13.4:1	—	—	—	—	—
1974	—	—	—	—	—	—	—	—	—
1975	2.11:1	3.26:1	—	—	—	—	—	—	—
1976	1.07:1	1.5:1	2.96:1	5.22:1	—	—	—	—	—
1977	*	13.9:1	*	8.22:1	—	—	—	—	—
1978	NA	3.96:1	NA	3.83:1	NA	10.25:1	1.9:1	2.3:1	NA

SCS: Spring Chinook Salmon
FCS: Fall Chinook Salmon
SHT: Steelhead Trout
CO: Coho Salmon
SO: Sockeye Salmon
NA: Data not available at time of publication
* Data too few to calculate benefits although the only adults recaptured so far have been transported fish

The time frame under which the research is conducted is another concern. Under the present system it takes three consecutive years to mark the juveniles and three following years to

analyze the number of returning adults. This means that six years are needed in many cases to determine the success of specific methods, release sites, collection systems, etc. When working within the confines of a highly dynamic resource and variable physical conditions, this time lag is often too large. Steps are being taken to reduce the number of years needed to gain the necessary data. Laboratory models are one such solution being considered by the various researchers.

"Operation Fish Flush" is a program related to transportation designed to enhance the survival of noncollected migrating juveniles to the Lower Columbia River. Fish Flush was initiated in 1979 at Lower Monumental, Ice Harbor and McNary Dams by the Walla Walla District; and at John Day Dam by the Portland District. It is designed to escort juveniles around noncollection dams by attracting them over the spillways with various spill patterns.

This is accomplished with a marine model of side-scan sonar, positioned on the powerhouse deck, scanning the upper levels of the forebay. A transducer positioned on the intake pier nose emits a sound beam which reflects on a fish's swim bladder and objects having a density different than water. The targets appear on an oscilloscope-type screen and are interpreted by the sonar technician.

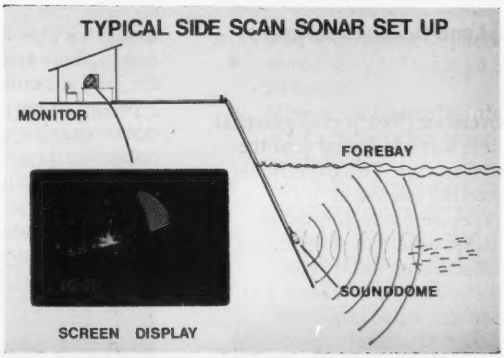
When appropriate concentrations of juveniles are seen building in the forebay, spillways are opened to provide predetermined volumes, patterns, and depths of spill. The success of the pattern being tested is determined by the sonar technician who monitors the movement of juveniles from the powerhouse over to the spillway. Although each dam has distinct flow patterns and consequently different juvenile behavioral patterns, some conclusions regarding the use of sonar have become clear:

☐ There are variations each year in the amount of water available for spill and the timing of the peak flows.

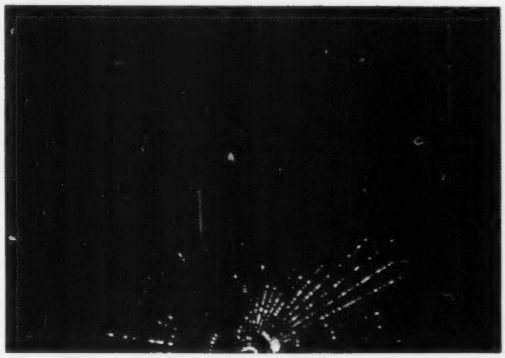
☐ Sonar monitoring can be used, under certain circumstances, to effectively direct spill patterns which stimulate juveniles to pass through spillways and away from powerhouse-induced mortality.

☐ Sonar spills can be used, in some cases, as effectively as random mass-volume spilling and at a considerable savings in hydroelectric production and revenues.

☐ To date, sonar monitoring has been used only to direct special spill patterns. Precise quantification of the number of juvenile fish being passed over the spillways is difficult, and the number of variables involved complicate the task. Portland District personnel are researching a variety of electronic tools and new sonar designs in an attempt to quantify the success of the program.



Schematic diagram of the sonar monitoring operation.



Fish targets on the sonar screen moving from right of center (powerhouse) to left of center (spillways) in response to water being spilled over the spillways.

With programs such as Operation Fish Run and Operation Fish Flush, the future of the Columbia River salmon and steelhead stocks looks bright. Research studies intended to reduce mortality, stress, and delay of the migrating juveniles will continue. We will work to improve the health and vigor of the young salmon as they struggle to reach the sea.

The ebb and flow of life and the land in the Pacific Northwest will persist, as will these anadromous species. Their story, their heritage, their struggle — the lure of the romantic salmon, will not be lost. ■

Events, Deeds & Deliber-ations

Atlantic Remote Sensing Land Ocean Experiment Conducted

During October and November 1980, a major coastal engineering field experiment was conducted near the Outer Banks area of North Carolina. This experiment collected data that advanced the science of determining how ocean waves were transformed as they progressed to shore, storm prediction techniques, and verification of data collection methods. This provided improved information on the processes and prediction of coastal erosion and led to improved methods and criteria for design of coastal engineering works.

The U.S. Army Coastal Engineering Research Center (CERC), a research facility of the Corps of Engineers, coordinated this multiorganizational experiment called Atalntic Remote Sensing Land Ocean Experiment (ARSLOE). The Corps' Field Research Facility at Duck, North Carolina was the operations center. Over 30 Federal and private agencies, including academic groups, pooled talent, equipment and funds to collect one of the most complete sets of data on ocean waves, how they traveled across the ocean, how they were affected by ocean currents such as the Gulf Stream, and how the ocean bottom affected their travel speeds and directions. A major facet of ARSLOE was the use of a number of remote sensing techniques to measure the many characteristics of waves and verify those measurements against more conventional oceanographic instruments.

The experiment was divided into three test sites: Land experiments near Elizabeth City, NC; oceanographic experiments near the Chesapeake Bay entrance and the Gulf Stream, and ocean waves and currents near Duck.

The surface verification for remote sensing of ocean waves consisted of buoys that were deployed in a 30 x 40 km area which consisted of nine waveriders for one dimensional spectra and seven buoys for directional wave spectra, and three meteorological buoys. In the nearshore area, a variety of current measuring systems were deployed in addition to seven wave staffs. Additional data consisted of bottom roughness by side scan sonar, bottom samples, wind speed and direction at seven locations, air temperature, water temperature, conductivity and bathymetric survey. Ground teams for the land site collected data on soil moisture, vegetation type and stress, and cultural features. The teams for the oceanographic experiment consisted of a surface ship collecting data on water temperature, salinity, suspended sediment and biological content.

The remote sensing techniques used were: airborne and surface radars, multispectral aerial photography,

airborne thermal detectors and specialized microwave and laser systems for measuring numerous ocean characteristics.

Scientists from Canada, France, Japan and Norway participated in ARSLOE. They brought newly developed oceanographic instruments for the measurement of waves.

The benefit of this experiment was information to verify mathematical wave models developed for use in predicting wave action on our coasts. The verification that remote sensing instruments, either in airplanes or in satellites, can measure such data to the degree necessary, has paved the way for better monitoring of the oceans in the future which will allow even greater predictive capability for storms and their effects on the coast.

There will be a future *Water Spectrum* article on the research results of the ARSLOE experiment. ■

Fish and Wildlife Service Seeks Comment on Proposed Mitigation Policy

The U.S. Fish and Wildlife Service is seeking public comment on the guidelines that it uses to protect and

conserve fish and wildlife that are affected by major environmental changes, the process known as "mitigation."

The Interior Department agency recently outlined and clarified the operating policy it uses to assist agencies which approve construction projects and other types of development in ensuring the adequate consideration of fish and wildlife interests. This draft mitigation policy was published in the September 9, 1980 *Federal Register*.

"Fish and wildlife resources belong to the people," Service Director Lynn Greenwalt said. "They are protected and managed for the people by Federal, state, and Indian tribal governments.

"When modifications of land and water threaten fish and wildlife and their habitat, Federal agencies are required by the Fish and Wildlife Coordination Act and other Federal laws to give equal consideration to their protection and to adopt justifiable measures in their projects to avoid or minimize losses and compensate for unavoidable losses."

The Fish and Wildlife Service is the major Federal agency involved in the management and protection of the nation's fish and wildlife resources. The Service does not issue licenses and permits for large-scale development projects, but assists development agencies to adequately consider fish and wildlife resources that may be threatened by project development.

After operating under a number of formal and informal policy guidelines on mitigation for many years, the Fish and Wildlife Service believes that an updated and comprehensive statement of policy will allow other government agencies and private developers to anticipate its recommendations for mitigation early in the initial phases of construction projects.

"A well-defined policy on mitigation would enable government and industry to avoid delays and assure the equal consideration of fish and wildlife resources with the other features and purposes of their projects," Greenwalt said.

Under the proposed policy, a five-part definition of this process developed by the President's Council on Environmental Quality forms the basis of the Service's overall goal of mitigating losses of fish, wildlife, and habitat from the disruptive impacts of land and water development. In summary, mitigation is described as a process by which these impacts are:

- Avoided by not taking a certain action, or parts of an action;
- Minimized by limiting the degree or magnitude of an action, or the manner in which an activity is conducted;
- Rectified by repairing, rehabilitating, or restoring the affected environment;
- Reduced or eliminated over the project's lifetime by preservation and maintenance operations; and
- Compensated for by providing substitute resources or environments.

During the consultation process between agencies, an appropriate level of mitigation is recommended by the Fish and Wildlife Service. It investigates how habitat modifications would lead to changes in an area's biological value to fish and wildlife. The mitigation measures it recommends vary according to the value and scarcity of the species and habitat affected. The two primary considerations are the presence of important species that have a high value to man or are critical to the maintenance of the ecosystem, and the relative scarcity of the particular habitat.

"What this draft policy does is clearly outline our stand on mitigation and reflect the way our role in mitigation, under legislative mandate, is being carried out by the Fish and Wildlife Service," said Greenwalt. "We hope the principle it embodies— adequate mitigation for important fish and wildlife resources when the environment is altered— might become more universally recognized." ■

Grand Isle, Louisiana is Site for Seawater Desalting

Grand Isle, Louisiana, one hundred miles south of New Orleans, has been selected as the site for construction of a seawater desalting demonstration plant, Secretary of the Interior Cecil Andrus has announced.

The island, which fronts on the Gulf of Mexico, suffers frequent water shortages. It was selected under a 50-million dollar program in which Congress has authorized construction of five plants to demonstrate state-of-the-art technology for conversion of saline or other impaired water to usable water. Virginia Beach, Virginia and Alamogordo, New Mexico were previously selected for demonstration plants.

Secretary Andrus said, "Such plants would make water managers and water planners aware of new options for solving problems of water quality or quantity. Applying advanced technology, as part of an operating water system, will provide a basis for judgment of the suitability of these processes."

Grand Isle was chosen from 20 candidate sites recommended to the Office of Water Research and Technology (OWRT). OWRT is the principal Federal agency concerned with all aspects of water resources research and development, and demonstration programs. OWRT sought nominations from the states, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, and the Pacific territories.

Grand Isle's permanent population of 3000 increases to 6000 in the summer. The town owns and operates its water system, but must also buy water from a water district which often cannot deliver because of shortages. Grand Isle industries frequently must import water at prices ranging up to $8 per thousand gallons.

The seawater desalting demonstration plant will use the latest in singlepass reverse osmosis technology. The usable water will be piped into the town's water system and the salt-laden brine will be returned to the sea.

The Grand Isle demonstration schedule calls for a predesign study and report to Congress in Fiscal Year 1981; design and construction planning, 1981-1982; and construction to start in 1983.

Virginia Beach and Alamogordo, selected in December 1978, have gone through the evaluation and predesign phase. The plans and specifications phase is about to get underway.

OWRT believes desalting may offer a cost-effective solution to long term water problems. Secretary Andrus said, "The final step of water research and development is demonstration which puts the developed technology on display, where it can be seen, evaluated, and considered by others with similar water problems. The Grand Isle demonstration plant will provide such an opportunity." ■

Atlantic Coast Ecological Inventory and Maps Available

The future design and siting of coastal developments and major energy projects along the Eastern Seaboard may be significantly influenced with the use of a new inventory and map series of fish and wildlife species and other ecological resources recently compiled by the Interior Department's U.S. Fish and Wildlife Service.

The "Atlantic Coast Ecological Inventory" is the first comprehensive series of maps of natural resources on the Atlantic Coast and is an important new planning tool for governments and industries that contemplate major developments in the coastal zone. A similar inventory of Pacific Coast resources is now underway by the Fish and Wildlife Service.

"This kind of information is designed to help planners locate their projects away from ecologically sensitive areas, such as important spawning grounds or the habitats of endangered species," says Under Secretary of the Interior James Joseph.

Developed with technical assistance from the U.S. Geological Survey, the Service's new inventory and maps depict the entire 76,000-square mile coastal zone, major land use designations, and all important fish and wildlife species and their habitats.

In addition to the map series, a 163-page narrative report, "Atlantic Coast Ecological Inventory — User's Guide and Information Base," is also available. The report provides detailed explanations and additional technical information about the ecological data plotted on the maps.

"We're very pleased with the products of this cooperative venture by the Fish and Wildlife Service and the Geological Survey," Joseph said. "Anyone concerned with the Atlantic coastal zone and its uses — from private industry to environmental organizations, to local, state and Federal government agencies — now has a significant tool with which to judge the potential effects of environmental changes on fish and wildlife. We see this inventory as an opportunity to reduce conflicts among government, industry, and the environmental community by providing sound information, graphically displayed, before proposed actions become disputes."

The map series has already seen use in a joint Federal-state oil spill simulation session in New York. Members of a regional oil spill response team, drawn from the Fish and Wildlife Service, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the U.S. Coast Guard, New York State, and other government agencies, used the maps to pinpoint concentrations of waterfowl and

other sensitive natural resources on the southern shore of Long Island during a September 1980 simulated ship grounding. Under national oil spill response programs, these drills are held periodically at various sites around the country.

Data collection and organization for this project was conducted under a 10-month, $234,756 contract with Dames & Moore of Bethesda, Maryland, an international engineering and earth science consulting firm. The biological data used to compile the inventories of habitat were drawn from Federal and regional agencies and the coastal zone management organizations in each of the Eastern Seaboard States. A $263,756 contract has been competitively awarded to Dames & Moore by the Service for a companion survey of ecological resources of the Pacific Coast, with completion scheduled by July 1981.

The maps are lithographically reproduced in five colors and distributed in a convenient 4x8-inch pocket-fold format. The 31 Atlantic Coast Ecological Inventory maps are formatted on 1x2-degree sheets and carry the same individual map names as the Geological Survey's topographic map series. The Maps are available individually or in sets for $2.00 per copy, and can be ordered by mail from the U.S. Geological Survey, Branch of Distribution, 1200 South Eads Street, Arlington, Virginia 22202, or the Branch of Distribution, Box 25286, Federal Center, Denver, Colorado 80225. Orders must include a check or money order payable to the "U.S. Geological Survey."

The narrative report, "Atlantic Coast Ecological Inventory— User's Guide and Information Base," includes detailed species information for the entire map series. It can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $5.00. ■

Manatee Protection Areas Proposed

Three manatee protection areas in the Kings Bay area of Florida's Crystal River have been proposed in the *Federal Register*.

Representing roughly 10 acres of underwater habitat, the proposal would restrict water-related activities, such as boating and swimming, between November 15 and March 31 of each year in the vicinity of several warm water springs where the endangered manatees congregate during winter.

Between 80 and 100 manatees— nearly one-tenth of the species' estimated total population— are thought to winter in Kings Bay. The slow-moving manatees are frequently injured in mishaps with boat traffic and in flood control gates. Many manatees bear scars from past encounters with boat propellers. ■

Final Environmental Impact Statement on Outer Banks Released

The Final Environmental Impact Statement (FEIS) has been released on the U.S. Fish and Wildlife Service's proposal to establish a national wildlife refuge on the Currituck Outer Banks of North Carolina.

The Service's Northeast Regional Office has proposed the purchase or acquisition of interest in all lands from the Virginia-North Carolina state line to the north edge of the village of Corolla to the Dare County line. Most of the land could be secured with conservation easements. Upland portions would be purchased with permanent residents and their children retaining life use. Parttime residents could use their property for 25 years if they had approved permits to build homes before December 31, 1979.

This proposal would provide protection for habitat used by thousands of water fowl wintering in Currituck Sound, as well as such endangered species as the bald eagle, peregrine falcon, and loggerhead turtle. The Service began to develop its proposal when it became apparent that fish and wildlife resources of the area were being threatened as a result of intensive efforts to develop the Currituck spit for recreational, second home, or retirement home use. ■

Errata

In the Fall 1980 *Water Spectrum*, it was erroneously reported that the dredge *Eagle 1* would replace the retired *Essayons* at the head of the U.S. Army Corps of Engineers' dredging fleet. In fact, the dredge *Wheeler* will become the Corps' flagship dredge. The *Eagle 1* is a private industry hull. The error is regretted. ■

Bookshelf

The Recovery Process In Damaged Ecosystems, by Virginia Polytechnic Institute and State University Distinguished Professor John Cairns, Jr., presents the results of a symposium held in Athens, Georgia, under the auspices of the Ecological Society of America. Sample chapter headings include "The Relationship Between Succession and the Recovery Process in Ecosystems," and "To Rehabilitate and Restore Great Lakes Ecosystems." 167 pages and index. Published by Ann Arbor Science Publishers, Inc., P. O. Box 1425, Ann Arbor, MI 48106.

Western Water Resources: Coming Problems and the Policy Alternatives, is a compilation of the proceedings of a symposium sponsored by the Federal Bank of Kansas City. The book is available from Frederick A. Praeger, publisher, Westview Press, 5500 Central Avenue, Boulder, CO 80301, for $25.

Scientific, Technological and Institutional Aspects of Water Resource Policy, edited by Yacov Y. Haimes, is also available from Westview Press, for $15.

The International Water Report, a quarterly newsletter edited by Judith M. Corcoran, provides the domestic manager, scientist, technician, educator and legislator with up-to-date developments in the water resources field throughout Europe, Asia, North and South America, Africa and Oceania. It also provides subscribers with recent knowledge of water development, supply and treatment; treaties and legislation affecting the global community, and accounts of water-related incidents around the world. Pertinent meetings are announced and reviews are included for new publications and products. This newsletter is available for $98.00 per year from Water Information Center, Inc., The North Shore Atrium, 6800 Jericho Turnpike, Syosset, NY 11791.

Land into Water — Water into Land, by Nelson M. Blake, is a study of water-related problems in Florida. This study of water management traces the intricate network of issues and influences leading to the present crisis in water resources. The author tells of successive efforts to manipulate and control the natural flow of water by the construction of elaborate engineering works. Emphasis is placed on two projects: the cross-Florida ship canal (later revised to a barge canal) and the draining of the Everglades to produce arable land. The book is available for $19.95 from the University Presses of Florida, 15 N.W. 15th Street, Gainesville, FL 32603.

Risk and Accidents in Outdoor Recreation Areas: Selected Papers, compiled by Dr. Richard L. Bury, is an informative report of papers written by three individuals for delivery at the 1978 Recreation Management Institute. The report involves accidents and liability that the National Park Service must frequently deal with as well as safety and prospects for the future. It is available for $1.00 from Texas A&M University, Department of Recreation and Parks, College Station, TX 77843. ■

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Coming Events

1981 National Water Conservation Conference on Publicly Supplied Potable Water Systems, Denver Hilton Hotel, Denver, Colorado, April 14-15.

8th Ocean Energy Conference, Washington, D.C., June 7-11.

Changes of Command

Major General Max W. Noah has become the commanding general of the U.S. Army Engineer Center and Fort Belvoir and commandant of the Army Engineer School, Fort Belvoir, VA. He was previously division engineer for the Corps' Huntsville Division in Huntsville, Alabama. He succeeded **Major General James L. Kelly** who retired from active duty.

Brigadier General Norman G. Delbridge, Jr. was named Assistant Chief of Engineers, Office of the Chief of Engineers, Washington, D.C. General Delbridge, who was formerly division engineer of the South Pacific Division at San Fransico, California, succeeded **Major General William E. Read. Brigadier General Homer Johnstone** succeeded General Delbridge in San Francisco General Johnstone's previous assignment was commander, Defense Contract Administration Services Region, New York.

In other Corps of Engineers general officer reassignments, **Brigadier General George K. Withers, Jr.** replaced **Major General Drake Wilson** as division engineer of the U.S. Army Corps of Engineers' European Division at Frankfurt, Germany. General Withers previously served as deputy assistant to the Deputy Chief of Staff for Operations and Planning, Department of the Army, Washington, D.C.

Colonel C. Ernest Edgar, III has been named division engineer for the U.S. Army Corps of Engineers' New England Division in Waltham, Massachusetts, effective in February. He succeeds **Colonel Max B. Scheider,** who will retire from active military duty. Colonel Edgar is currently Commandant of Cadets at Virginia Military Institute, Lexington, VA.

Colonel James J. Harmon has become Tulsa District Engineer, Tulsa, Oklahoma. He succeeds **Colonel Robert G. Bening,** who has retired. Colonel Harmon was assistant director of Civil Works, Pacific, in the Office of the Chief of Engineers, Washington, D.C.

Colonel John A. Poteat, Jr. was named division engineer for the U.S. Army Corps of Engineers' Huntsville Division in Huntsville, Alabama. Colonel Poteat had been the executive to the Assistant Secretary of the Army for Civil Works, Washington, D.C.

Colonel George R. Robertson has been named as deputy director of Civil Works, Office of the Chief of Engineers, Washington, D.C. He succeeds **Brigadier General Hugh G. Robinson,** who became division engineer of the Corps' Southwestern Division, Dallas, Texas. Colonel Robertson was executive director of Civil Works, Office of the Chief of Engineers, in Washington.

Lieutenant Colonel Larry S. Bonine became Little Rock District Engineer, Little Rock, Arkansas, in January. He replaces **Colonel Dale K. Randels,** who retired. Colonel Bonine was previously assigned to Headquarters, Personnel Support Command, U.S. Army, Europe.

Lieutenant Colonel Christos A. Dovas became Chicago District Engineer, also in January. He succeeded Lieutenant **Colonel Howard N. Nicholas.** Colonel Dovas was formerly director of Engineering and Housing, U.S. Military Community Activity Karlsruhe, Federal Republic of Germany. Colonel Nicholas has been assigned to Fort Benjamin Harrison, Indiana.

Dr. Lydia Waters Thomas, Associate Technical Director, MITRE Corporation, McLean, Virginia, has been named to the Chief of Engineers Environmental Advisory Board. Dr. Thomas, awarded a doctor of philosophy degree in cytology from Howard University in 1973, is responsible for the technical quality of documents produced under government contracts at MITRE. ■

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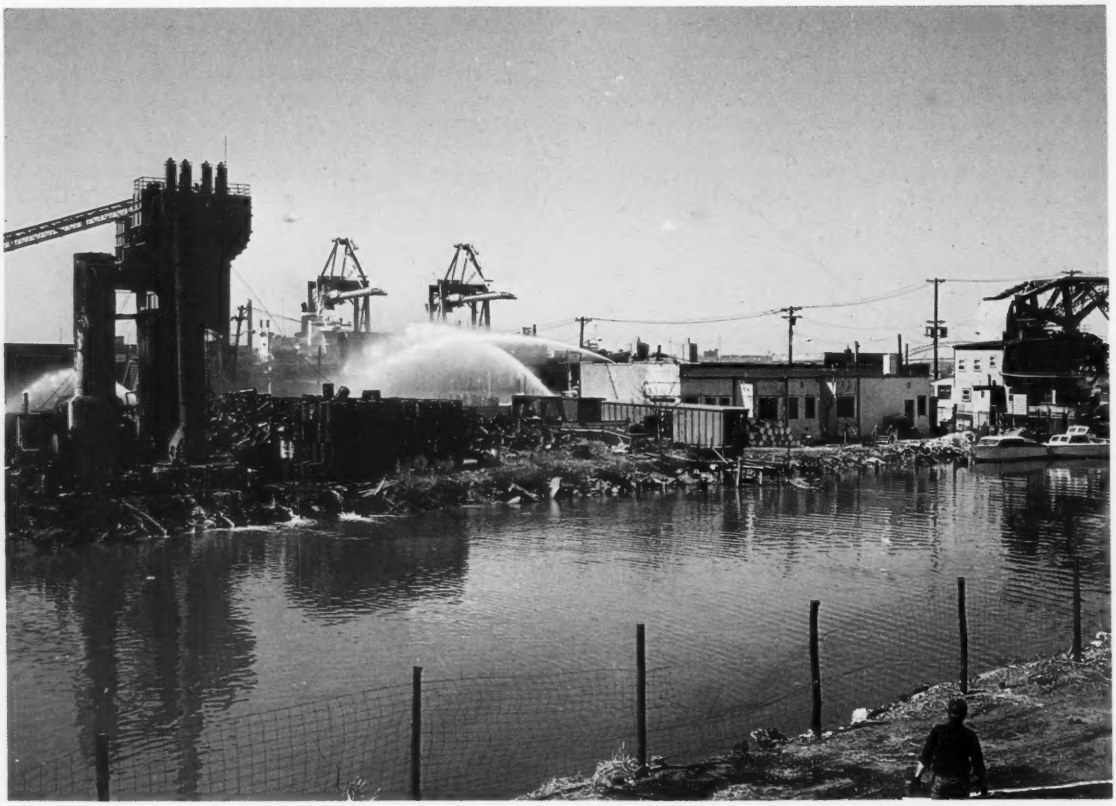
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